Ontario

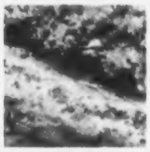
DRAINAGE GUIDE FOR ONTARIO

PUBLICATION 29

MINISTRY OF AGRICULTURE, FOOD AND RURAL AFFAIRS

Ontario






DRAINAGE GUIDE FOR ONTARIO

PUBLICATION 29

Editor

Sid Vander Veen, P. Eng., Drainage Coordinator
Ontario Ministry of Agriculture, Food and Rural Affairs

Acknowledgements

The first edition of the *Drainage Guide for Ontario* was authored in 1957 by Ross W. Irwin, professor at the University of Guelph. He also coordinated several subsequent updates to the guide. Through research and extension to farmers, contractors and practicing drainage engineers, Professor Irwin advanced the art and science of soil water management and drainage throughout Ontario and the humid regions of the United States. He's a member of the Ontario Agricultural Hall of Fame and a recent inductee into the International Drainage Hall of Fame established in the Agricultural Engineering Department at Ohio State University.

The 2007 revision to the Drainage Guide was coordinated by the following team:

Ross Irwin, professor emeritus, University of Guelph, Steve Cronsberry, president, Land Improvement Contractors of Ontario and the following Ontario Ministry of Agriculture, Food and Rural Affairs staff: Valerie Anderson, Doug Aspinall, Andy Kester, Jim Myslik, P. Eng., Arlene Robertson and David Rouleau.

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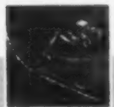
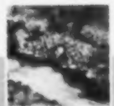



Brief History of the Drainage Guide for Ontario

First published in 1957, this is the eighth edition of the Drainage Guide. Here's a brief look at the development of the guide over the past 50 years.

1956 – Responsibility for the design of tile drainage systems transfers from the Ontario Agricultural College (OAC) to the new engineering service of the Ontario Department of Agriculture Extension Branch, and brings a new opportunity for branch staff.

1957 – OAC produces the first *Drainage Guide for Ontario* in 24-page mimeo form, based on the American Society of Agricultural Engineers *Tentative Recommendation for the Design and Construction of Tile Drains in Humid Areas.*

1960 – Publication 29, *Drainage Guide for Ontario*, joins the list of publications produced by the Department, and includes 256 soil types.

1966 – A revised guide includes specifications for pipe substitutes when clay and concrete tile are in short supply.

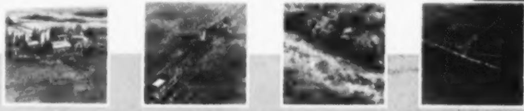
1973 – This edition includes a significant number of revisions and is printed in the new A-4 format. With 275 soils, the guide includes the Ontario Farm Drainage Association (OFDA) standards of construction and the voluntary quality control of the new plastic pipe. The design code is upgraded for internal drainage of the soil and touches on subsoil stoniness of economic interest to drainage contractors. The material section is enlarged and ASTM standards of quality tables are included. Outlet pipes are now specified to replace old hot water tanks. Pipeline crossings are included, and plastic tubing is barely mentioned as grading is still done with grade stakes. By 1973, OFDA contractors upgraded their ability to design tile systems through courses, and there's a steady transfer of licensing and tile design to contractors.

1976 – The guide now contains the technical information for the regulations to the *Agricultural Tile Drain Installation Act, 1990.* The same design code and soil list is included, with emphasis on calculation of discharge and drain size. The construction section becomes a standard rather than a how-to section.

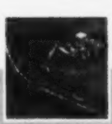
1984 – The guide goes metric. Improvements based on new research and the present system of soil classification are added, with little similarity to the old, and based on the Canada Land Inventory. There were now 309 soils types, and an improved method for calculating drain pipe diameter.

1986 – Surface drainage and sub-irrigation are now recognized in the guide. Other additions include a revised construction section, technical information for calculating drain spacing and a procedure for examining a soil profile. This edition is also printed in French.

2007 – This current revision reflects changes in agricultural land management and environmental awareness, and also includes soils for northern Ontario. As with all revisions, the 2007 guide was reviewed and revised by a team of dedicated professionals.





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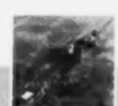


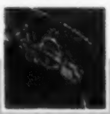

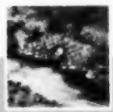

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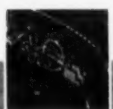
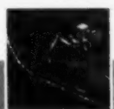
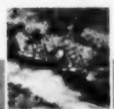




1. General

1.1 Purpose

The *Drainage Guide for Ontario* (guide) is the technical reference document for the regulations to the *Agricultural Tile Drainage Installation Act, 1990*. It's also designed as a useful guide for licensed drainage contractors, drainage superintendents, drainage engineers, agricultural engineers, and others interested in the planning, design, inspection and proper construction of agricultural drainage systems, and/or as a basis for writing specifications. Landowners, farm operators and others looking for an understanding of drainage system design, water management and construction technology may also find the information useful.

Recommendations in this guide are specific to the province of Ontario, general in nature and serve as guidelines for designers of agricultural subsurface drainage systems. The guide doesn't eliminate the need for further on-site enquiries into soil conditions, land topography, crops to be grown and economics of investment. Modifications may be required to adapt recommendations to local conditions and current or future tillage practices. Recommendations in this guide are based on the assumption that adequate outlets exist or can be provided.

The guide will be revised and updated as new information becomes available.

1.2 Landowner Responsibilities

Drainage contractors are responsible for ensuring the drainage system is professionally designed and pipe materials installed will allow entry of water into the pipe and convey it to the outlet. Landowners, and not contractors, are responsible for the following items:

Outlet

Before installing a tile drainage system, secure a legal outlet for the system – a location where collected water can be legally discharged without adversely affecting downstream landowners. An outlet may include:

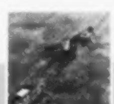
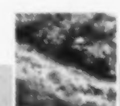
- natural watercourses
- municipal drains
- agreement drains

Obtain agreement (written permission) for outlets in the following cases:

- if property of another landowner is crossed to outlet into a municipal drain or watercourse, from lower landowner(s)
- for outlets into a private drain, road ditch or tile located on a neighbouring property
- for connections into a municipal drain, from the local municipality

Soil Response

Landowners are responsible for ensuring soil responds to tile drainage. Soil may contain chemicals that adversely affect the long-term performance of tile drains. Some farm practices adversely affect the vertical flow of water into the soil profile. Poor subsurface drainage can result from soil compaction, particularly in high traffic areas such as vineyards where soil may already be compacted, inhibiting movement of water through the soil to the tile. Contractors


may provide advice to landowners on ways to improve soil drainage. Continuous cash cropping often creates a denser soil layer, reducing the efficiency of subsurface drains. Maintaining and building organic matter in the soil improves soil structure and keeps soil permeable so excess water can readily reach the drain.

Permits

The landowner must obtain any necessary easements or permits well in advance of construction, and contractors must ensure all easements and permits are obtained before their work begins.

Private Utilities

The landowner is responsible for identifying the location of any buried cables, waterlines, septic systems or other private utilities on the property. The landowner is also responsible for ensuring points where the drain and buried utility may intersect are marked and uncovered. The contractor is not responsible for damages to private utilities that are not clearly identified by the landowner.

Public Utilities

Prior to the design of the drainage system, the landowner must determine if any public utility facilities or rights-of-way will be encroached or crossed. In this case, the landowner must advise the public utility during the design stage and acquire any regulatory approval required prior to construction. The public utility must be contacted again, at least 48 hours before construction, to locate and mark the facilities. Work should not begin until the public utility, contractor and owner are satisfied that all requirements and safety precautions are met.

Site Clean-up and Restoration

The landowner is responsible for site clean-up and restoration, and may arrange for the contractor to perform these functions. Site clean-up and restoration may include:

- spreading any surplus soil over the surrounding field
- removing materials from the work site such as large stones, roots, etc.
- repairing, replacing or restoring fencing and other farm property
- removing any surplus pipe material, bands, debris and ties
- any other special arrangements

1.3 Investment

Drainage is an investment designed to produce sufficient increased returns within a reasonable period of time. The longer subsurface drainage systems function properly, the greater the returns. Good soil management practices (particularly in fine-textured soils) help ensure a drainage system works well over a long period of time. These practices include returning crop residue to the soil and including deep-rooted legumes in crop rotation.

1.4 Subsurface Drainage

Subsurface drainage is the managed removal of water from the soil surface and soil profile to provide suitable growing conditions for crop production, while considering the impact on the water ecosystem. Subsurface tile drains manage the shallow water table level within a soil profile, providing a suitable environment for plants to survive and grow within a reasonable length of time after rain. The water table is only managed to the depth of the subsurface drain.




1.5 Surface Drainage

Surface drainage manages the removal of surface ponded water, where necessary, with shallow ditches that can be crossed with farm equipment. Consider the impact on where surface water collects and discharges. Surface drainage reduces the volume of water that would otherwise percolate into soil. By reducing the water that subsurface drains discharge, surface drainage makes the entire system more efficient. Consider the following with surface drainage:

- adapted to flat land where subsoil is fine-textured and dense
- has little positive effect on soil trafficability for seedbed preparation
- doesn't reduce soil profile wetness
- removes water from soil surface but doesn't lower the water table in soil profile
- should be practiced before investing in subsurface drainage
- surface inlets connected to subsurface drains may be used to manage water removal from depressional areas

1.6 Land Smoothing

Many flat, fine-textured soils have shallow depressions on the surface. Ponding of water in these surface depressions for prolonged periods is detrimental to crop production. Removing these slight depressions through land smoothing reduces surface ponding and provides more uniform percolation of water into soil. Shallow vegetated surface ditches bordering fields also help remove excess surface water.

1.7 Sub-irrigation

Sub-irrigation for field crops is a water table management practice with the potential to improve subsurface water quality. It's an expensive practice that's very site specific and requires specialized design. Sub-irrigation applies to areas with low subsoil permeability and an adequate water supply. Here are a few considerations for sub-irrigation:

- Necessary permits are required to take water.
- A supplementary water supply must exist, or be developed, for the irrigation mode.
- Design the water management system for both drainage and sub-irrigation modes.
- Size the system to supply the maximum water required during a peak use period, including percolation losses.
- Plan main drains and laterals parallel to the ground surface.
- Limit the length of laterals to provide adequate capacity for drainage and sub-irrigation.
- Install laterals deeper than recommended in Table 2 to provide an adequate head of water.
- Lateral drain spacing for combined sub-irrigation/drainage systems is dependent on soil type, use Table 1 to determine drain spacing.
- Pipe size must provide the desired flow.
- Install water level control structures where necessary to ensure the water table is held within a 0.3 m (1 ft) variation in elevation.
- Maintenance of a sub-irrigation system is critical to its annual use.

Note: Owners considering use of a combined drainage/sub-irrigation system should seek professional advice about the suitability of the site to produce the desired crop.

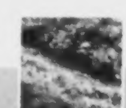


Table 1. Lateral Drain Spacing for Sub-irrigation as a Percent of Spacings Recommended for Drainage (See Table 3)

Soil Texture	Percent of Drainage Spacing
Silt	45
Loam, silty clay loam	70
Sandy loam	80
Loamy sand	90

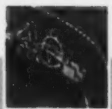
1.8 Organic Soils

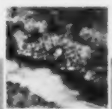
There are no general recommendations for the drainage of organic (muck type) soils in this guide. Each case requires consideration and advice from an experienced designer of drainage systems for organic soils. Problems unique to organic soils include initial soil consolidation, water table control, dike construction, seepage, pumping, etc.

Avoid drainage of shallow muck soils, 450 mm (1.5 ft) or less in depth, over sand or impermeable clay. The life of these organic soils is short and subsurface drainage is usually not an economically viable investment.

1.9 Mineral Soils

Recommendations in this guide deal with the drainage of agricultural mineral soils only, as they form the majority of agricultural land. Installing subsurface drains is not often advised in marl – which isn't a soil – or in layered bedrock at shallow depths.



2. Planning and Design

2.1 How to Use this Guide

The first step to develop a drainage plan is evaluating the feasibility of drainage by:

- consulting this guide
- gathering local drainage experience
- reviewing soil survey information
- considering wetland and natural land features
- identifying applicable legislation and regulations
- determining economic factors

Base the design and construction of agricultural drainage systems on:

- available outlets
- appropriate soil investigations
- general water movement and ponding patterns in areas to be drained
- topographic surveys
- proposed land uses

2.2 County Soil Survey Maps

Ontario has a wide variety of different soils, and drainage needs and opportunities vary with each soil. The soil series in Ontario is based on existing soil maps and is divided into major soil groups according to drainage need. As soil mapping continues, and with newer concepts in soil classification, some re-correlation on older soil maps is necessary and revisions will be made as re-correlation progresses. It's also important to consider that minor unmapped variations in soil occur within farms.

In general terms, soil maps and reports are used to determine:

- the nature and properties of soils at a given location
- the suitability of a given location for a particular agricultural use
- the need for improved drainage

Small areas of wet soils can't be shown on maps at the scale commonly used for soil surveys, and a detailed on-site soil survey may be required to identify these areas in the fields to be drained.

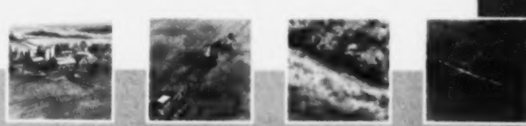
Drainage practices are linked to the soil profile characteristics, and structure, texture, depth, stoniness and wetness are the most relevant. These characteristics form the basis of a survey to classify soils into soil series units. Survey maps and accompanying reports are useful information for drainage purposes.

Soil reports for most counties are available in public libraries and may be available on the Government of Canada website, Canadian Soil Information System, *http://sis2.agr.gc.ca/cansis/*

2.3 Collecting Soil Information

Obtain the soils report for the area to be drained, and then:

- Find the location of the farm on the soil map and record the soil map notations.



- Refer to the soil map legend to determine the meaning of each symbol in the notations.
- Determine the soil series from the expanded map legend.
- Consult the table of contents in the soil report to find sections describing the specific soil series. Read these sections for detailed land use and soil technical information.
- Verify conclusions by inspecting the site in the field. Dig into the soil to learn about the internal drainage, and use post holes or trenches to reveal subsoil characteristics.
- Figure A2 maps the general distribution and class of Ontario subsoils, and reflects soil drainability.

2.4 Subsurface Drainage Design Code

Soil-Water Problem Classes

Two broad classes of soil-water problems are recognized in this guide – groundwater soils and surface water soils.

Groundwater soils are generally permeable and water logging results from rising groundwater. There are two important design criteria: mid-spacing water table elevation as determined by crop root requirements and the drainage coefficient rate. The steady-state drain spacing equation in Appendix B is useful for this design. One limitation for lowering the water table in these soils is the available depth of the outfall.

Surface water soils have relatively impermeable subsoils and vertical movement of water is restricted. The soil hydraulic conductivity is low and gravity drainage is restricted to water movement in soil cracks and fissures. Water movement ceases when soil peds swell. Most water movement occurs in the cultivated surface layers. Secondary drainage treatment, such as surface drainage, is often needed in these soils.

The Ontario soils listed in Table 2 are grouped according to the soil characteristics most relevant to the design of subsurface drainage systems. The two primary characteristics are the rate water moves through the soil profile and the degree of wetness before subsurface drains are installed (natural drainage). Two other important characteristics are the soil profile depth, and the topographic position and land slope.

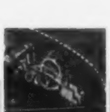
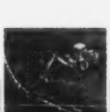
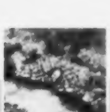
For this guide, each soil series found in Ontario is correlated with a drainage design code (Table 2). Depth and spacing recommendations for each soil series are in Table 3 based on the drainage design code.

Most soil information is extrapolated or estimated from test results or field experience, and some is based on test data. Local conditions and experience may indicate that deviations from these recommendations are desirable and necessary.

Drainage Design Code

Four symbols make up the drainage design code, i.e. S3W8

- The *first symbol* is either S or G and indicates the source of the water (Table A1). S indicates water on the surface because of a restricting layer not more than 1 m (3 ft) below. G indicates where groundwater is, or has been, close to the surface. These classes are determined and mapped during the county soil survey.

- The *second symbol* is a number associated with the first symbol. There are six classes for surface water soils and three classes for groundwater soils. Appendix A, including the illustrations in Figure A1, summarizes the information. Figure A1 illustrates the method used by pedologists to show the range in a soil profile, i.e. the left edge and right edge. The average location for a tile drain is noted in each drainage profile. The general distribution of these soils is shown in Figure A2. Each soil is described in Appendix A, Table A1 and is a function of the soil hydraulic conductivity shown in Appendix A, Table A3.
- The *third symbol* is a capital letter representing the natural drainage class, described in Appendix A5. This symbol doesn't change after tile drains are installed.
- The *fourth symbol* is a topography slope class, outlined in Appendix A, Table A6. The Canada Land Inventory (CLI) slope classes are too broad (1-6) for drainage works, and this guides uses a code with nine symbols.

Source: Soil Classification for Agricultural Drainage in Southern Ontario. University of Guelph, School of Engineering Publication. 126-51, 1980. P.S. Chisholm, A. Baytalan, R.W. Irwin.

2.5 How to Use Table 2

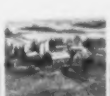
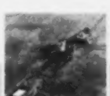
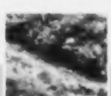
Enter the soil series name determined in Section 2.3 and determine the drainage design code.

Table 2. Ontario Soil Series and Related Drainage Design Code***

Southern Ontario

Soil Series	Drainage Design Code	CLI Class with Drainage	CLI without Drainage	Hydrologic Soil Group
Achigan	G2I4	4f		B
Alberton	S1I2	3 i/w	5	D
Allendale*	S3P2	3 w	5	C
Alliston*	G3I2	-	-	B
Almonte	S1W7	-	-	C
Ameliasburg	S6W8	-	-	D
Ancaster	S3W8	-	-	B
Anstruther	S6W7	4fm		B
Appleton	G1W9	-	-	B
Atherley	S1P2	3 w	5	D
Ayr	G3P2	3 w/i	5	C
Bainsville	S3P2	2 w	5	C
Balderson	G1I2	-	-	B
Ballymote	G3P3	2w	4w	C
Bamford	G3I2	-	-	B
Bancroft	G3W8	-	-	A
Barrhaven	S6P2	6rw		C
Bass	S1I2	-	-	D
Battersea	S2I5	-	-	C
Bearbrook	S1P2	3 w/d	5	D
Becketts Creek	S3I4	-		C
Belmeade	S5VI	4 d/w	5	D
Bennington	S3W8	-	-	B
Berriedale	G2W8	-	-	A
Berrien	S3I5	-	-	C
Beverly*	S2I4	-	-	C
Binbrook	S2I4	-	-	C
Blackburne	S5P1	-		D
Blackwell	SIPI	2 w	4	D
Bolingbroke	G3W5	-	-	A
Bondhead*	G1W8	-	-	B
Bookton	S3W6	-	-	B

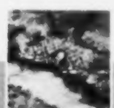
Soil Series	Drainage Design Code	CLI Class with Drainage	CLI without Drainage	Hydrologic Soil Group
Boomer	S4W2	3 i/m	5	B
Borromee	S6VP1	-		D
Borthwick	G2VP1	-		C
Brady*	G2I5	-	-	B
Brandon	S1P2	3w		D
Brant*	S3W8	-	-	B
Brantford	S2W7	-	-	C
Bridgman	G3W9	-	-	A
Brighton	G2W7	-	-	A
Brisbane*	G3I2	-	-	B
Brockport	S6M9	-	-	B
Brooke	S6P3	-	-	C
Brookston	S2P2	2 w	5	D
Bryanston	G1W8	-	-	A
Bucke	S3W8	-	-	B
Buckham Bay	G2W8	-		A
Burford*	G3W4	-	-	A
Burnbrae	S6W3	-	-	B
Burnstown*	G1W9	-	-	B
Burpee	G3P1	5 w	6	C
Burrittts Rapids	S5VP1	-		D
Buzwah*	SIW7	-	-	C
Caistor	S2I5	-	-	C
Caledon	G3W4	-	-	A
Camilla	G3I2	-	-	B
Campbell*	S1W7	-	-	C
Cane*	S2P1	2 w	5	D
Carlsbad	G2W4	-		A
Carp*	S2I5	-	-	C
Carsonby	S3P2	-		C
Casey	S416	-	-	B
Cashel	S2M6	-	-	C


Southern Ontario

Soil Series	Drainage Design Code	CLI Class with Drainage	CLI without Drainage	Hydrologic Soil Group
Castor*	S3I3	-	-	C
Chateauguay	S3W4	2d		B
Cheney	G2P2	5wf		C
Chesley	S2P2	2 w	5	D
Chinguacousy*	S2I5	-	-	C
Christy	G1PI	6 w/p	6	C
Clyde	S1PI	2 w	5	D
Codrington	S3I4	-	-	C
Colbome	G3W4	-	-	A
Colwood*	G1P2	2 w	5	C
Conestoga	G1I4	-	-	B
Conover	S2I4	-	-	C
Constance Bay	G2W4	-		A
Cooksville	S6I4	-	-	B
Corkery	S5VP1	-		D
Craigleith	S2I4	-	-	C
Cramahe	G3W8	-	-	A
Crombie	GIP2	2 w	5	C
Dalhousie	S1I4	2d		D
Dalton	S3I4	-	-	C
Darlington	G1W8	-	-	B
Deloro*	G1W8	-	-	B
Donald	G3I2	3 i	5	B
Donnybrook	G3WS	-	-	A
Dorking	S2P1	4 d/w	5	D
Dumfries*	G3W8	-	-	A
Dummer*	G1W8	-	-	B
Dundonald	S3W6	-	-	B
Dunedin	S2W8	-	-	C
Dunrobin	G2P2	5wf		C
Dwyer Hill	S3P2	3w		C
Eamer	G1W7	-	-	B
Earlton*	S4I6	-	-	B
Eastport	G3W9	-	-	A
Edenvale	5315	-	-	C
Eganville*	G1W8	-	-	B
Ekfrid	S1I6	-	-	D
Elderslie	S2I4	-	-	C
Eldorado	G1W8	-	-	B
Ellwood	S2I5	-	-	C
Ellwood	S6I2	-		B
Elmbrook	S2I5	-	-	C
Elmira	G2P1	4w/i	5	C
Elmsley	S6W3	-	-	B
Embro	S3I4	-	-	C
Emily*	G1I4	-	-	B
Englehart	S3P2	4 w	5	C
Evanturel*	S4W9	-	-	B
Fallowfield	S6I2	5r		B
Fanshawe	G3I4	-	-	B
Farmington	S6W3	-	-	B
Ferndale	S2P2	2 w	5	D
Flamboro*	G3P2	4 w	5	C
Floradale	G3I3	-	-	B
Font	G3W9	-	-	A
Fonthill	G3W4	-	-	A
Fox*	G2W7	-	-	A
Foxboro	G1P2	2w	5	C
Franktown	S6I3	-	-	B
Freeport	G1W6	-	-	B
French Hill	G3W6	2ft		A
Galesburg	G1W9	-	-	B
Galesburg	S6W6	3p		B
Gananoque*	S1W7	-	-	C
Gerow	S6P1	-	-	C
Gilford	G3P2	4 w	5	C
Glendale	S5VP1	-		D
Gobles	S2I7			C
Gordon*	S1I2	-	-	D
Goulbourn	S5VP1	-		D
Granby	G2P2	3 w	5	C
Grand	G1W1	2 i	4	B
Greely	S5VP1	-		D
Grenville*	G1W7	-	-	B
Grimsby*	G2W7	-	-	A
Guelph*	G1W8	-	-	B
Guerin*	G1I2	-	-	B
Gwillimbury	G3I4	-	-	B
Haldimand	S1I5	-	-	C
Hampden	S5I2			D
Harkaway*	G1W7	-	-	B
Harrisburg	S3W5	-	-	B
Harriston	G1W8	-	-	B
Harrow	G3W9	-	-	A
Havelock	G3W9	-	-	A
Hawkesville	G3P1	4 w/i	5	C
Haysville	G3I2	3 i	4	B
Heidelberg	G3I4	-	-	B
Hendrie	G3I2	-	-	B
Herbets Corners	G2I4	-		B
Hespeler	G3P2	4 w/i	5	C
Highgate	G3I4	-	-	B
Hillier	S6W8	-	-	B
Hillsburgh	G3W9	-	-	A
Hinchinbrooke*	GIP2	2 w	5	C
Honeywood	S3W8	-	-	B
Howland*	G1I5	-	-	B
Huron	S2M6	-	-	C
Innisville	G1P1	4 w	5	C
Ironside	S3W6	3f		B
Jeddo	S1P2	4 w/d	5	D
Jockvale	G2W4	3f		A
Kagawong	S6W8	-	-	B
Kanata	S6W7	-		B
Kars	G3W4	-	-	A
Kelvin	S2P2			D
Kemble*	S2P4	-	-	C
Kenabeek	G2P3	6 w	6	C
Killean	S1I2	-	-	B
King	S2W7	-	-	C
Kintyre	G3W6	-	-	A
Kirkland	G3W2	3 i/mn	5	A
Kossuth	G1I4	-	-	B
L'Achigan	G2I5	-	-	B
Lambton	S3I5	-	-	C
Lanark	S2I5	-	-	C
Landsdowne*	S1I2	-	-	D
Laplaine	S1P1	-		D
Leith	S3W8	-	-	B
Leithrim	S6W3	-	-	B
Lemieux	S5VP1	-		D
Lily	G1P1	6 w/p	6	C
Limoges	G2W6	-		D
Lincoln	S1P2	4 w/d	5	D
Lindsay*	S2P2	2 w	5	D
Lisbon	G3W8	-	-	A



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Southern Ontario

Soil Series	Drainage Design Code	CLI Class with Drainage	CLI without Drainage	Hydrologic Soil Group
Listowel	G1I2	-	-	B
Little Current	S6W8	-	-	B
Lockport	S6M9	-	-	B
London*	G1I2	-	-	B
Lonsdale	S5V2			D
Lovering	S2I5	-	-	C
Lowbanks	GIV2			B
Lyons*	G1P1	3 w	5	C
MacDonald	S3P4	2w		D
Macton	G1I2	3 l	5	B
Magnetawan	G1P4	-	-	C
Mallard*	G2I5	-	-	B
Malton	S2P2	2 w	5	D
Manion Corners	S5VP1	-		D
Mannheim	G1W6	-	-	B
Manotick	S3W8	-	-	B
Maplewood	S3P2	2 w	5	C
Marchhurst	S6W5	-		B
Marionville	S3P2	2 w	5	C
Marsh	S5V1	-	-	D
Maryhill	G1P2	2w	4	C
Matilda	G1I4	-	-	B
Matson	S3I4	-	-	C
Medonte	S1WS	-	-	C
Melbourne	S1W6	-	-	C
Mer Bleue	S5P1	-		D
Mersea	S5VP1	-		D
Miami	S2W7	-	-	C
Mill	S3P1	3 w	5	C
Mille Isle	G2W4	4fm		A
Milliken	G1I2	-	-	B
Minesing	S1P1	2 w	5	D
Mississauga	S1P2	5 w/r	6	D
Monaghan	S2I4	-	-	C
Monteagle*	G1W6	-	-	B
Morley	S2P2	3 d/w	5	D
Morrisburg	S2I4	-	-	C
Moscow*	S2P2	2 w	5	D
Mountain	S3I4	-	-	C
Muck	S5V1	-	-	D
Muirkirk	G3P3	2w	4w	C
Munroe	S5VP1	-		D
Munster	G3W6	-		A
Muriel	S2M7			C
Murray	S3I4	-	-	C
Napanee*	S1P1	3 d/w	5	D
Nelson	S2M6	-	-	C
Nepean	S6W5	6r		B
Newburgh	S3W8	-	-	B
Newcastle	S3W8	-	-	B
Niagara	S2I5	-	-	C
Nipissing	S3I3	-	-	C
Nissouri	G1P3	2w	4w	C
Noiharn	S3WS	-	-	B
Normandale	G1I5			B
North Gower*	S2P2	2 w	5	D
Oakland	G3I3			B
Oakview	S5V2			D
Ohsweken	S3P2	2w	4w-5w	C
Oneida	S1W5	-	-	C
Ontario	S2W4	-	-	C
Osborne	S3I2	-	-	B
Osgoode	S2P2	2 w	5	C
Oshtemo	G2W7	-	-	A
Osnabruck	S2P2	4 w/p	5	D
Osprey	G1W8	-	-	B
Otonabee*	G1W7	-	-	B
Otterskin	S3P4	-	-	C
Parkhill*	G1P1	2 w	5	C
Peat	S5V1	6 w	6	D
Peel	S2I5	-	-	C
Pelham	G3W9	-	-	A
Perch	S1PI	4 d/w	5	D
Percy	S3W8	-	-	B
Perth	S2I5	-	-	C
Petherwick	G1P2	2 w	5	C
Phipps*	S1PI	3 w	5	D
Piccadilly	S3I4	-	-	D
Pike	S1W7	-	-	C
Pike Lake	G3W8	-	-	A
Piperville	S3I6	2f		C
Plainfield	G3W9	-	-	A
Pontypool	G3W9	-	-	A
Preston	G3I3	4 i/r	6	B
Queensway	S6W6	-		B
Ramsayville	G2I4	-		B
Reevecraig	G2P2	3w		C
Renfrew	S1I2	-	-	D
Rideau	S1I2	-	-	D
Ridgeville	G3I2	-	-	B
Rivard	S1P1	3dw	5w	D
Rubicon*	G2I5	-	-	B
Sargent	G3W8	-	-	A
Saugeen	S2W8	-	-	C
Schomberg	S2M6	-	-	C
Scotland	G3W7			A
Seely's Bay	S2M6	-	-	C
Senaca	G1W7			B
Seneca	G1W7	-	-	B
Shashawandah	S6W4	-	-	B
Sidney*	S1P2	3 w	5	D
Silver Hill	G1P3			B
Simcoe	S2P2	2 w	5	D
Smithfield	S2I5	-	-	C
Smithville	S2W7	-	-	C
Snedden	S1I2	-	-	D
Solmesville	S2I5	-	-	C
South Bay	S1W5	-	-	C
Springvale	G3M6	-	-	A
St. Clair	G2P2	2w	4w	A
St. Clements	S2W6	-	-	C
St. Damase	S3I4	-		
St. Jacobs	G3W2	-	-	A
St. Peter	G3W3	-	-	A
St. Samuel*	G2P3	6 w	5	C
St. Thomas	G3W8	-	-	A
St. Williams	GIP2			B
Stafford	G1I2	-	-	B
Stapledon	G2I4	-		B
Ste. Rosalie	S1P2	3 w/d	5	D
Stockdale	G1P2	2 w	5	C
Strathburn	S1P3	3w	5w	D
Styx	G1V2			B
Sullivan	G3W4	-	-	A
Summerstown	S5VP1	-		D
Tansley	S2I5	-	-	C

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Southern Ontario

Soil Series	Drainage Design Code	CLI Class with Drainage	CLI without Drainage	Hydrologic Soil Group	Soil Series	Drainage Design Code	CLI Class with Drainage	CLI without Drainage	Hydrologic Soil Group
Tavistock	S3I4	-	-	C	Waterloo	G3W9	-	-	A
Tecumseh	G2I5	-	-	B	Watford	G3W7			A
Teeswater	S3W8	-	-	B	Watrin	G3P2	6 w	6	C
Tennyson*	G1W8	-	-	B	Waupoos	S2M6	-	-	C
Thames	S2I5	-	-	C	Wauseon	S3P1	3w	5	C
Thorah	G2P3	6 w	6	C	Wayside	G3I2	-	-	B
Thorndale	G1I4	-	-	B	Welland	SIP2	4 w/d	5	D
Thwaites	G1W9	-	-	B	Wellesley	S2I2	-	-	C
Tioga*	G3W5	-	-	A	Wemyss	G1I4	-	-	B
Toledo*	S2P2	2 w	5	D	Wendigo*	G3W8	-	-	A
Trafalgar	S6I4	-	-	B	Wendover	S1I2	-	-	D
Trent	S3I4	-	-	C	Westmeath	G3W5	-	-	A
Tuscola*	S3I4	-	-	C	Whitby	G1I2	-	-	B
Tweed	S6W8	-	-	B	White Lake*	G3W5			A
Uplands	G2W8	-	-	A	Whitfield	S6W8	-	-	B
Vanessa	G3P2			C	Wiarton	G1I4	-	-	B
Vars	G1W8	-	-	B	Wilmot	S2P2	2 w	5	D
Vasey*	G1W9	-	-	B	Wilsonville	G3W7			A
Vaudreil	G2P2	3w		C	Winona	S3I5	-	-	C
Vincent	S2W8	-	-	C	Woburn	G1W8	-	-	B
Vineland*	G2I5	-	-	B	Wolford	S2W8	-	-	C
Vinette	G2I4	-		B	Wolsey*	S1P1	2 w	5	D
Vittoria	S3I4			C	Wooler	S3W8	-	-	B
Wabi	G1W6	-	-	B	Woolwich	G1W4	-	-	B
Walshear	S3W6			C	Wyevale	G3W3	-	-	A
Walsingham	G2I2			A					

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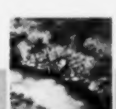
Soil Series	Drainage Design Code	CLI Class with Drainage	Hydrologic Soil Group	Soil Series	Drainage Design Code	CLI Class with Drainage	Hydrologic Soil Group
Abitibi	G2W5	5FM	A	Black Sturgeon	S1M 5	2C	C
Abram	S1I4	2C	D	Blake	S3 I1	2C	C
Agnewe	S3P4	3W	C	Blanche	S3W9	3D	B
Albany	S1I	3D	D	Bluett	S2V2	4W	D
Alcock	G2I2	4F	B	Blythe	S5V2	5HK	D
Alpine	S3M 5	3C	B	Bob Lake	G3I2	4F	B
Ansonville	G2I4	3C-4F	B	Bonfield	S1P2	4WD	D
Arbor Vitae	S3P4	3W	C	Boulter	S2I5	3D	C
Arthur	S3I3	3FM	C	Bradley	S3I4	3F	C
Atwood	S2I5	2C	C	Breakneck	S3P2	4W	C
Audrey	S2P2	4W	D	Brentha	S6W5	5R	B
Avery	S3I2	3F	C	Brethour	S3P2	2CW	C
Azilda	S3P2	3W	C	Broadtail	G2W7	4FM to 7PR	A
Bain	G3V2	5WF-6W	C	Bucke	S3W5	4FM	B
Baird	S5V1	*	D	Burditt	G1P2	5PW	C
Baldwin	S3W7	2C	B	Burnet	S3W2	3FM	B
Balmer Bay	S2P2	4WD	D	Burning	S1V2	4W	D
Barnhart	S2I5	2C	C	Burpee	G3V2	6WF	C
Basket	S2P2	3W	D	Burt	S5V2	4HF	D
Bearle	S3I5	3C	C	Burton	S5V2	4HF	D
Beartrack	G2P2	4W	C	Cabett	S5V1	*	D
Belle Vallee	S5V2	4HF	D	Cache Lake	S5V2	2F	D
Bergland	G2P2	4FW	C	Callum	S5V2	3HK	D
Berry Lake	S5V2	4HF	D	Cane	S3P2	4W	C
Binabich	S3W3	2C	B	Capreol	S3P2	4W-5W	C
Biz	S3P2	4W	C	Carmody	S3W8	4TP	B
Black Bay	S1P1	3W	D	Carpenter	S2P4	3W	D
Black River	S3M 5	3C	B	Carterton	S5V2	5HK	D



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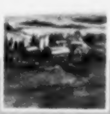
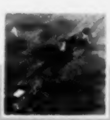
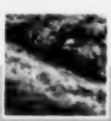
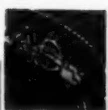
Soil Series	Drainage Design Code	CLI Class with Drainage	Hydrologic Soil Group
Casey	S3I4	4F	C
Casimar	S2P2	3DW-4WD	D
Cedar	S3I5	2C	C
Chamberlain	S5V2	4HFL	D
Chartand	S1I7	3D	D
Cherriman	G2P2	5WF	C
Chiswick	S5V2	4HK	D
Christy	G1P2	6WP	C
Chrystal Falls	S5V2	5HK	D
Claxton	G3P2	5FW	C
Clearway	G1W8	5P	B
Clegg	S1M5	3C	C
Coderette	S5V2	5HK	D
Collins	S2P2	4D	D
Contact Bay	G1W9	4FM to 6TP	B
Corbeil	S5V2	4HK	D
Corn	S1I2	2C	D
Coutts	G1I8	5P	B
Couttsville	S5V2	5HL	D
Cranberry	G3P2	3WF	C
Crozier	S2P4	3W	D
Crystal Falls	S5V2	5HF	D
Curran	S5V2	3H	D
Current River	G1I1	5P	B
Cutler	G3M2	4FM	A
Dack	S1W7	3D	C
Daltes	G1I2	5P	B
Dance	S3I2	3F	C
Dawson	G1W7	3D-4P	B
Dayton	S3V2	4W	C
Deception	G1W7	6FM to 7TR	B
Delamere	S2W7	3D	C
Delray	S1W5	3C	C
Denman	G1M5	4P	B
Devitt	S2I4	3C	C
Devlin	S2I4	2C to 3F	C
Dewart	G3I2	3F to 4F	B
Dilke	G3P2	4FW	C
Dokise	G2W7	4FM	A
Dorion	S1I2	2C	D
Drurey	S5V2	6HFK	D
Drury	S5V2	6HFK	D
Dryden	S5V2	3HF	D
Ducharme	S1W7	2C to 3T	C
Duchesnay	S5V2	5H	D
Dune Sand	G2?2	6I	A
Dunnet	S3M5	3D	B
Dymond	G1I8	4P	B
Eag:le Lake	S5V2	4KHF	D
Eakett	G3P2	6WF	C
Earlton	S3I4	3C-3D	C
Ecclestone	S3I4	2C-3C	C
Elk Pit	G3W9	5TF to 6T	A
Ellice	G1W8	3P	B
Emo	S1P2	3W	D
Englehart	S3P2	4W-5WF	C
English	G1P2	6PW-6PTS	C
Espanola	S5V2	5HFK	D
Estaire	S5V2	3HF	D
Evanturel	S3W9	3T-6T	B
Everard	S1W	*	C
Everend	S3P2	4W	C
Falardeau	S3P2	3DW	C
Farmington	S6W2	6PR	B
Favareau	S3P2	4W	C
Flamingo	S2W7	3T	C
Fleck	S5V2	6HFL	D
Ford	S2P2	4W	D
Formal	G1W3	6PS	B
Fort Frances	S1V2	4W	D
Fort William	G2I2	3FM	B
Frechette	S3W7	2C-6T	B
Frederick	G2P2	5FW	C
Fremlin	S3M5	4FM	B
Frere Lake	S5V2	6HL	D
Fynxal	S1W8	3FD	C
Gaffney	G2P2	4W-5W	C
Gaffney Lake	S5V2	4F	D
Gameland	G2I4	3F	B
Gawase	S6W2	6R	B
Genesee	S5V2	5HK	D
Giante	G3W4	5FM	A
Glen	G3I1	5FM	B
Goughe	S3V2	5FW	C
Goulaise	G2V2	6FW	C
Gouvereau	G2P2	4WF	C
Grace	S1I5	2F	D
Grass	S5V2	5HL	D
Grassey	G1W9	3FM	B
Gullwing Lake	S5V2	4F	D
Guy Lake	G2P2	4WF	C
Haddo	S1P2	3W	D
Hagar	G2P2	4W	C
Haileybury	S1W8	2C-6T	C
Hallam	S3I2	3F	C
Hammerhead	S3I5	3D	C
Hanbury	S1I7	2C-3D	D
Hanna	G1W9	5PS-7TP	B
Harfred	G2W5	4FM	A
Harley	S5P2	3H	D
Harold	S5V2	7HL	D
Harrey	S3P2	3W	C
Harris Hill	S5V2	5HFK	D
Hartman	S1P2	4W	D
Haultain	S2W9	5P to 7TP	C
Hearst	S1I4	3C	D
Heaslip	S5V2	4KHF	D
Hilliard	S5V2	4HF	D
Hilton Beach	G3W7	4FM	A
Hilton Lake	S5V2	3H	D
Himsworth	S3I4	3D	C
Hughes	S5V2	4H	D
Hyndman	S1W2	2C	C
Ilford	S3I5	3F	C
Ingram	S5V2	6HFL	D
Innes Lake	S5V2	4HKF	D
Isbester	G1I2	5P	B
Jaffray	G3W7	5FM	A
Jamot	S1P2	4WD	D
Janden	G1I5	4P	B
Jarvis River	S1M5	5TD	C
Jeannie	G3W77	7TSP	A
Jocelyn	S5V2	3H	D
Jumbon	S5V1	*	D
Kanimiwiskia	S5V2	6F	D
Kapuskasing	S3M5	3C	B
Kawashegamuk	S3V2	4W	C
Keenoa	S3P2	4W	C

Northern Ontario

Soil Series	Drainage Design Code	CLI Class with Drainage	Hydrologic Soil Group
Kellar	S5V2	4HFL	D
Kenabeek	G3P2	5WF	C
Kenogami	S5P2	6HFK	D
Kerns	S5V2	3H	D
Ketchinig	S5V2	6HFK	D
Killaby	S3M4	3F	B
Kim	S2P2	4W	D
Kingsford	S3M4	3F	B
Kushog	S5V2	6H	D
Kynoch	G1M9	5TP	B
La Vallee	S1W8	3T	C
Lappe	S1P1	4WD	D
Larder	S5V2	4KHF	D
Laurence	S3M5	3FM	B
Leeville	S5P2	4HFL	D
Linkor	S5V1	*	D
Lowther	S2M5	3C	C
Macintyre	S5V1	*	D
Magnetewan	S3W9	4T - 6T	B
Makobe	G1I4	5P-7P	B
Mallard	G3I7	4FM-7PR	B
Manders	S5V2	3K	D
Marie	S3V2	5WF	C
Marritt	S3M7	2C	B
Marshal	G1I2	4P-6PR	B
Marten	S3W5	4F	B
Mary	G2W5	4FM	A
Matheson	G1W2	5PS	B
Maybrook	S5V2	3H	D
McCool	S1I2	3WD	D
McKellar	S3P1	3W	C
Medette	G2I2	4FM-6RS	B
Melgund	S3V2	4W	C
Melick	G1W9	3T	B
Menary	G3M2	4F	A
Mennin	S1M2	2C	C
Mickle	S2P2	3W	D
Mietzle	G3W3	5FM	A
Milberta	S1V2	6W	D
Milford	S5V2	3HL	D
Millerand	S1V2	4W	D
Minnitaki	S1P2	3W	D
Miscampbell	G2I2	4FM	B
Misema River	S5V2	3HF	D
Mission	G3P1	5WF	C
Monteagle	G1W9	5TP-7PR	B
Moose	G1P2	5PW-6P	C
Morley	G3W8	5P	A
Morson	G2V2	5W	C
Mud Lake	S5V2	3F	D
Mudcat Creek	S5V2	4HFK	D
Muddy Lake	S5V2	2F	D
Muller	S2W8	2C to 3T	C
Murillo	S5V1	*	D
Muskosung	G3?W7	6FM	A
Musselle	S3P2	3W-5W	C
Naiden	S3W4	3F	B
Neebing	G3I1	4F	B
Nellie	S1W5	3D	C
New Liskeard	S1P2	2CW-4W	D
Newfeld	S3P2	4W	C
Noelville	S3I5	2C	C
Nolalu	G1W4	6TP	B
Norembega	S5P2	5FL	D
North Branch	S3I5	2C	C
Notre Dame	S5V2	3H	D
Nugget	G3P2	5W	C
O	S5V2	*	D
Oak	S3M5	2C	B
Off	G1W8	3FM	B
Orbit Lake	S5V1	*	D
Organic	S5V2	N/A	D
Oskondoga	S1I2	6TP	D
Otterskin	S3I7	4F	C
Ouellette	S1P2	3DW-4WD	D
Ouimet	S1I1	3D	D
Paipoonge	S1W3	2C	C
Parket	S1P2	3DW	D
Parrish	S3I5	2C	C
Parry Sound	S5V2	4KHF	D
Pass	S5V2	4HF	D
Passer	S5V1	*	D
Pearl	G3W6	6F	A
Pearson	G1I6	5P	B
Pedlow	S5V2	5HF	D
Peganels Lake	S5V2	4HF	D
Penassen	S5V1	*	D
Pense	S3I4	3C-3DW	C
Phelans	G3W9	6FM	A
Pinewood	G3I2	4FM	B
Playfair	S3P2	3W	C
Plum	S1W5	2C to 4P	C
Porquis	S3I4	3C	C
Powassan	S3P2	3W	C
Pyne	G2I2	3F-4F	B
Quire	S3P2	3W	C
Raft Lake	S5V2	3KH	D
Rainy River	S5V2	3K	D
Raithe	S5V1	*	D
Recollect	G3V2	6W	C
Redvers	S2W2	2C	C
Richardson	G2W2	4FM	A
Ridger	G2P2	6W	C
Ridout	G1I5	6PR-7PR	B
Robitaille	S2V2	4W	D
Rock	N/A8	7R	N/A
Rockbound Lake	S5V2	5HF	D
Rockland	VAR7	7r to 4FM & 3D	N/A
Rose	S1I5	2C	D
Rowe	G3W5	5FM	A
Ryland	S1P4	4W	D
Sables	G1P2	5PW	C
San Pierre	S3P2	3W	C
Sasaginaga	S5P2	6HL	D
Scaden	G1W8	4P to7PT	B
Sellars	S3W3	2C	B
Sesekinika	S5P2	3H	D
Shenston	S5V2	5FL	D
Shetland	S1P2	4W	D
Siamese	S3P2	4W	C
Sibley	S2P	3W	D
Siflet	S3V2	4W	C
Silver	S3I2	2C	C
Sioux	S1W2	3D to 4TE	C
Slate River	G2W4	3FM	A
Sleeman	G3M5	3FM	A
Smoke	G2P2	4W	C
Solvan	S3P2	4W-4DW	C

Northern Ontario							
Soil Series	**Drainage Design Code**	**CLI Class with Drainage**	**Hydrologic Soil Group**	**Soil Series**	**Drainage Design Code**	**CLI Class with Drainage**	**Hydrologic Soil Group**
Spronger Lake	S5V2	2F	D	Vasey	S6W8	6PR	B
St Joeseph's	S6W2	6R	B	Vermillion	G1W8	4TP-6PR	B
Stinson	S3M7	2C	B	vERNER	G2I5	4F	B
Strawberry	G1P1	5WP	C	Veuve River	S3I5	2C	C
Sturgeon Falls	G2P2	4W	C	Wabi	G1W	5P	B
Sturgeon River	S5V2	3F	D	Wade	S5P2	4HK	D
Sunderland	S3V2	5W	C	Wahnapitne	S5V2	2H	D
Sunstrom	S5V2	5HL	D	Wamsley	S3W4	2C	B
Sutton Bay	G1P2	6P	C	Warren	G2P2	5WF-6WF	C
Tarbutt	G1P2	5PW	C	Wausing	G1W5	4TP	B
Tarentorous	S1M5	3D	C	Weird	S3W8	3T	B
Thistle	S3W5	3FM-4F	B	Wemyss	G1I2	5PR&7R	B
Thompkin	S1M5	2C	C	Wendigo	G3W9	4FM-6TS	A
Thornloe	S1P2	3DW-4WD	D	Wickens	G1P2	5WF	C
Thunder Lake	S5V2	4F	D	Wildnerness	S2I2	2C	C
Thwaites	S3W8	2C	B	Wildrice Lake	S5V2	5HF	D
Tomiko	S3P2	3W	C	Willbank	S3P2	4FW	C
Tomstown	S5P2	6HFL	D	Wistiwasing	S5P2	4HK	D
Tovell	G3V2	6W	C	Withington	G2I4	4F	B
Treaty	S3P2	3W	C	Wolf	S3P4	3W	C
Tribal	S2P2	3W	D	Wolf River	S5V1	*	D
Tunis	S3P2	4W	C	Wolfpup	G3W3	5FM	A
Turner	G2V2	6W	C	Wolseley	S1I2	2C	D
Twin Cities	G2P1	4W	C	Wood	S3P2	3W	C
Twin Falls	G2V2	4W-6W	C	Woodyatt	S3P2	3W	C
Twyning	G1V2	6W	C	Woolley	S3W5	4F-4FM	B
Uno Park	S5V2	5HL	D	Worthington	G3W5	4FM	A
Val Cote	S2W7	3C-5T	C	Yellek	S5V2	4H	D
Van Horne	S2W8	3T	C	Zealand	G3P2	4WF	C

* Soil series having phases over bedrock. The hydrologic grouping for the rocky phases of these soils should be reduced one group (i.e. C reduces to B).
** CLI class not available.
*** A drainage design code has been assigned to every soil series; however, the effectiveness of subsurface drainage must be assessed on an individual site basis.

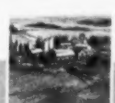
Table 2. Additional Information

Canada Land Inventory Ratings

Table 2 provides additional information for special engineering projects. In Ontario, published Canada Land Inventory (CLI) ratings are for soils assuming drainage is in place. The CLI ratings (Table A7) given in the third column are for current CLI maps where excess water or inundation is the major hazard. The rating corresponds to application of the CLI system when the requirement for drainage is recognized only in poorly and very poorly drained mineral soil series. Exceptions to the general rule include three well-drained soil series – Boomer, Grand, Kirkland, and five imperfectly-drained soil series – Alberton, Donald, Haysville, Macton, Preston. In all eight exceptions, inundation by overflow from watercourses is an agricultural hazard. In contrast, CLI ratings without drainage (fourth column for southern Ontario only) are an estimate of agricultural capability when necessary drainage is not in place.

Hydrologic Soil Groups

Hydrologic soil groups estimate runoff from precipitation. They are grouped according to water intake rate after prolonged wetting (measures infiltration capacity), and are interpretations based on United States Department of Agriculture – Soil Classification System criteria for hydrologic soil groups. The interpretation for each soil series is derived from data for soils in that series.




2.6 How to Use Table 3

With the first two symbols of the drainage design code, use Table 3 for a basic design recommendation of a subsurface drainage system. Table 3 provides depth and spacing recommendations for lateral drains for field crops.

Table 3. Depth and Spacing Recommendations for Lateral Drains for Field Crops

Drainage Design Code	Depth of Drain mm (in.)	Drain Spacing Cash Crops m (ft)	Surface Drains Needed?	Remarks
1	2	3	4	5
S1	600-650 (24-26)	6-12 (20-40)	Yes	Subsurface drainage not feasible unless soil structure is well defined when subsoil is wet
S2	600-700 (24-28)	6-15 (20-50)	Yes	
S3	700-1,000 (28-40)	6-15 (20-50)	Yes	Quicksand may be present
S4			Yes	Shallow soil barrier layers limit drain effectiveness
S5	Special investigation required		Yes	Water control works may be needed
S6	600 (24)		Yes	Shallow soil over bedrock limits design possibilities
G1	800-1,000 (32-40)	10-15 (33-50)	No	
G2	850-1,000 (34-40)	10-15 (33-50)	No	Quicksand may be present
G3	900-1,200 (36-48)	10-15 (33-50)	No	Quicksand may be present

Note: Fine sandy loam and sandy loam soils in Class S3, G2 and G3 require envelope protection.

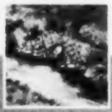
Column 1: Drainage Design Code

- Contains the first two symbols of the drainage design code selected from Table 2.
- Reflects the source of the drainage water problem and the soil drainage characteristics (refer to Table A2).

Column 2: Drain Depth

- Recommended range in depth to the bottom of the trench for lateral drains.
- Design depth should be within the range, and will depend on land slope, soil profile, topography and outlet elevation.



Column 3: Lateral Drain Spacing

- Recommended range in lateral drain spacing when using systematic or pattern drainage systems.
- Actual spacing selected depends on the degree of drainage needed for crops to be grown, and is often an economic decision. Higher annual investments in cash crops, compared to field crops, may mean closer spacing. Lateral drain spacing is also influenced by drain depth, field dimensions, cropping and cultivation pattern, and physical properties of the soil.
- Where a random drain pattern is used to drain isolated wet spots, seepage lines and springs, drain spacing is usually not a design factor, but future system expansion should be considered.

Column 4: Surface Drainage

- Recommends surface drains be used in conjunction with subsurface drains, or where surface drainage is considered to be a feasible solution to a surface water problem.

Column 5: Remarks

- Includes additional information to consider when designing and constructing a subsurface drainage system.

In Table 3, depth, spacing and drain locations recommendations are affected by crops grown (small grains, forage or cash crops) and economics, and should be based on site conditions including soils, topography, groundwater and outlets. Optimal rooting zone conditions are achieved through many combinations of tile spacing and depth. Consider soil series, soil permeability and stratification, desired drainage coefficient and degree of surface drainage, when choosing spacing and depth.

Figure 1 illustrates how wide and deep drain spacing gives similar results to shallow and narrow spacing. In the same soil type, shallow and narrow spacing achieves optimal root zone conditions in a shorter period of time and less total water volume is removed.

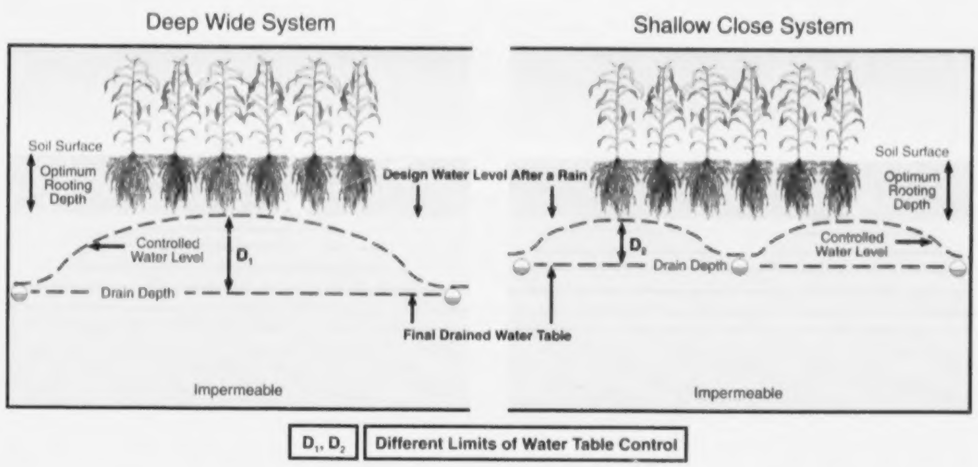


Figure 1. Comparison of Shallow Narrow Spacing vs. Deep Wide Drain Spacing

Maximum spacing – 15 m (50 ft) is the maximum recommended spacing between parallel lateral drains. Fields don't usually have enough uniformity in drainage characteristics or surface elevation to ensure uniform field drying at greater spacing, even though mathematical calculations suggests drain spacing may be greater.

Minimum spacing – 6 m (20 ft) is the minimum recommended spacing between parallel lateral drains. This drain spacing is an economic decision, and drainage of small depressional areas and specialty crops may need even closer spacing.

If a random or combination system is required, design it to accommodate more intensive drainage in the future. This is done by designing main and submain drains large enough to accommodate flow from lateral drains that might be added later.

If a drainage system is used for sub-irrigation, develop suitable drainage and soils criteria for the design (see Section 1.7).

Example Problem
Determine the depth and spacing for subsurface drains to be installed on lot 9, concession VI, Howick Township, Huron County. The principle crop grown is soybeans.

Here's how to find the solution:

- Locate the farm on the Huron County soil map by lot and concession. The map shows the soil is classified as Harriston loam. The soil report states the entire soil profile is stony and may present construction difficulties.
- From Table 2, Harriston soil series is listed under the drainage design code as G1W8.
- Table 3 at soil group G1 shows drain depth should be 800-1,000 mm (32-40 in.). Soybeans are a cash crop so drain spacing of 10-15 m (33-50 ft) is recommended.
- Surface drainage is not required. Surface inlets may be needed for the undulating nature of this well-drained soil. No additional information is given under the remarks column.
- Actual spacing depends on the degree of drainage the farmer wants and can afford for the crop, and is about 15 m (50 ft) for soybeans. Lateral drain depth depends on the outlet and local topography. As spacing gets closer, less depth is needed, and in the case 800 mm (32 in.) will work.

Calculate lateral drain spacing from a theoretical equation when technical information is available on soil profile characteristics and soil physical properties. A popular drain spacing equation is in Appendix B illustrating design parameters. If the hydraulic conductivity of soil is known through measurement or estimation, drain spacing is calculated using Dr. S.B. Hooghoudt's ellipse equation for homogeneous soils.

Recommendations on drain depth and drain spacing are based on research data in Ontario and the experience and practical observation of experts in this field. The recommendations are revised as new information is available.

2.7. Drainage of Special Crops

Special attention is warranted for the design of subsurface drains for high-value crops including fruits, nursery stock, vegetables and turf. The additional cost for closer lateral drain spacing is




small compared to the value of an orchard. Recommendations in Table 4 are based on row spacing rather than soil characteristics for these specialty crops.

These crops are very susceptible to the injurious effects of poor drainage. In a fruit orchard, for example, the depth of rooting usually determines the size and productivity. Soil should have little or no free water in the top 600-1,000 mm (24-40 in.) – except briefly after a heavy rain – during blossoming and fruit-setting periods. To intercept seepage and prevent prolonged flow into lateral drains, install an interceptor drain along the higher end of the orchard. This addition will also deter roots from entering lateral drains.

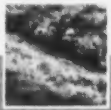
TABLE 4. Depth and Spacing Recommendations for Lateral Drains for Special Crops

Crop	Crop Row Spacing m (ft)	Drain Depth mm (in.)	Drain Spacing m (ft)	Remarks
1	2	3	4	5
Apples, dwarf	3 x 4 x 1 or 1.5 (10 x 13 x 3.3 or 5)	750 + (30 +)	6-9 (20-30)	Every other row, some sites drainage is not necessary
Cherries, sweet	6 x 3 (20 x 10)	900-1,200 (36-48)	6 (20)	Every row
Cherries, sour	6 x 6 or 4 (20 x 20 or 13)	750 + (30 +)	6-12 (20-40)	Every row, or every other row, some sites drainage is not necessary
Grapes	2.5 to 3 row (8-10)	750 + (30 +)	2.5-3 (8-10)	Every row, every other row in sandy sites
Peaches, Nectarines	6 x 3 (20 x 10)	900-1,200 (36-48)	6 (20)	Every row
	5 x 3 (16.5 x 10)	900-1,200 (36-48)	5 (16.5)	Every row
Pears, Plums, Apricots	6 x 3 or 4 (20 x 10 or 13)	750 (30)	6-12 (20-40)	Every row
Vegetable Crops on Mineral Soils		750 + (30 +)	4.5-6 (15-20)	Surface inlets in depressional areas may be needed
Vegetable Crops on Muck Soils		900-1,200 (36-48)	6-12 (20-40)	Moving towards larger diameter laterals with filter, refer to Section 1.6

2.8 Planning the Drainage System

Contractors should prepare a plan of the proposed subsurface drainage system to use during construction and copy the owner as a record of installation. The plan records the location of utilities and should be based on elevations established by a survey.






The plan will include details about location, size and grade of drains, accessories used in the construction and location of utilities. This topographic plan also provides the basis for obtaining tenders on the cost from several drainage contractors.

Before Construction

- All work follows a definite plan, which has been drawn, or considered, in advance of the construction.
- Contractor and owner inspect the job site to agree on work to be done, and obtain necessary easements/permits and/or facilities and outlets required for the installation (see Section 1.2 Private Utilities).
- Document and agree on the scope and cost of the work. Any changes during construction are also agreed on and documented.

After Construction

- Mark all plan changes on the plan made during construction, and any hazards encountered that may affect future maintenance.
- Contractor provides the landowner with a plan of the work as installed in the field, when construction is complete.
- Consider filing a copy of the plan with the property deed and the municipality. An aerial photograph of the completed work is also a useful record.

2.9 Outlet

Water collected in drainage systems must not discharge where it will damage other landowners, and sufficient outlets are required for a proposed subsurface drainage system. The design of outlets is discussed in Section 8 of this guide.

Ontario drainage laws govern outlets and where applicable, legally register outlet agreements for future protection of all parties. Legal considerations and procedures for obtaining an outlet are in OMAFRA Factsheet, *Drainage Legislation*, Order No. 89-166.

2.10 Drainage Coefficient

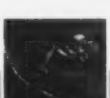
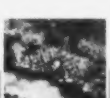
The drainage coefficient is the drainage rate the main drain can transfer water from the soil profile above the drain in a specific area. It's a value selected to provide adequate drainage for future crops and is expressed in mm/day (in./day). Use the rate to calculate the required pipe diameter for water transport and, less frequently, to determine drain spacing.

The drainage coefficient may need to be increased:

- for high value crops
- where crops have a lower tolerance to wetness
- in soils with a coarse texture
- when there is little or poor surface drainage
- where planting and harvest times are critical

The following drainage coefficients are recommended for subsurface drainage in Ontario mineral soils under normal surface drainage conditions and where no surface water is admitted directly into the subsurface drain. Apply these criteria only to wet land area to be drained. Increase the area to include any surface runoff from higher land and consider future uses for the area.



- 9 mm/day (⅜ in./day) for improved forage and general grain crops
- 12 mm/day (½ in./day) for cash crops
- 20 mm/day (¾ in./day) for high-value specialized crops

Where surface water is admitted into the subsurface drain, the flow design is based on:

- drainage coefficient from the previous paragraph
- plus 25 mm/day (1 in./day) for the area drained into open inlets
- plus 15 mm/day (⅝ in./day) for the area drained into blind inlets

Apply these criteria to the watershed area likely to contribute surface water to the surface inlet. This calculation is shown in Example 2 in Section 2.11. This recommendation applies to all crops except high value vegetable crops that suffer scalding from ponded surface water. For these crops, install surface inlets in depressional areas and provide a drainage coefficient of 35 mm/day (1⅜ in.) for the area contributing surface water to the surface inlet.
Note: In almost every case, the drain pipe diameter controls the rate of flow rather than the type of inlet, unless flow restrictors are used in the riser pipe.

2.11 Main Drain Pipe Diameter Selection

The design diameter of a drain pipe depends on the drain grade, internal hydraulic roughness of the pipe and the volume of water carried in a 24-hour period. Water volume depends on physical properties of soil, depth and spacing of drains, and area drained. When designing main and submain drains for random or combination systems, choose a pipe size to accommodate the flow from the area if it drained systematically.

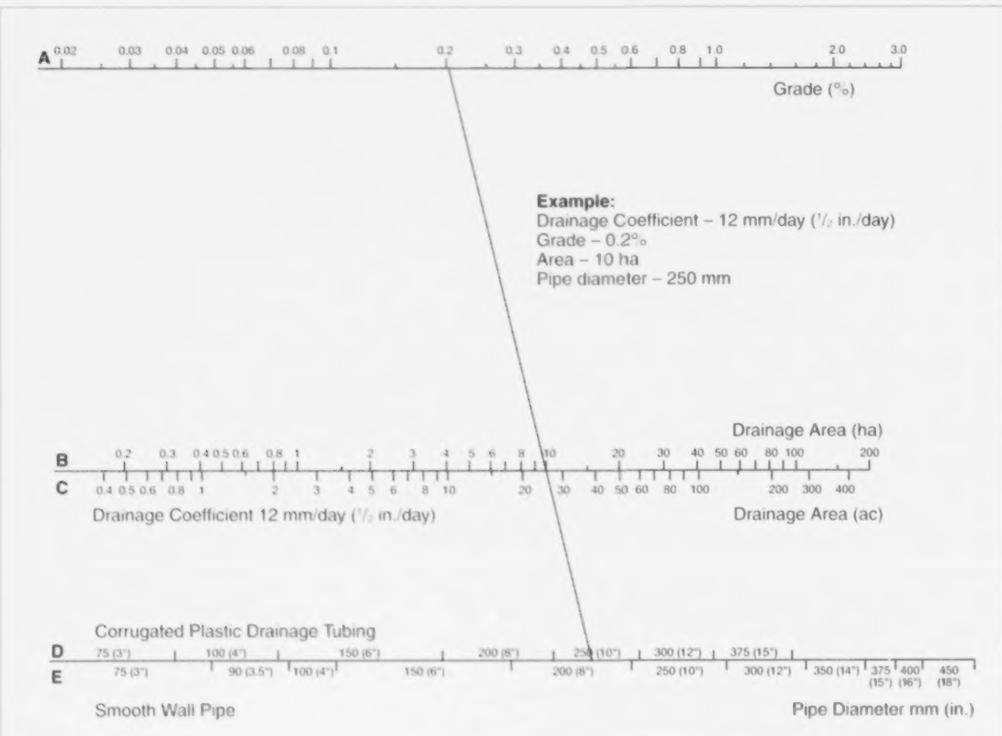
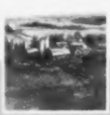
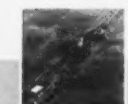
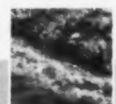


Figure 2. Nomograph for Selection of Main Drain Size


Determining Pipe Diameter

There are two methods for obtaining main drain pipe diameter in this guide – the nomograph method and the graphical method.

Nomograph Method (Figure 2)

Select the required pipe diameter from Figure 2. Knowing the proposed drain grade (A), the area to be drained (B), corresponding to a 12 mm/day (½ in./day) drainage coefficient (C), join these points with a straight edge and read off the required pipe size – (D) if corrugated plastic drainage tubing is used, or (E) if smooth-wall plastic, well-laid clay or concrete drain tile is used.

For example, a main drain on a grade of 0.2% (0.2 m/100 m or 0.2 ft/100 ft) used as an outlet for 10 ha (25 ac) of land at a drainage coefficient of 12 mm (½ in.)/day will require a 250 mm (10 in.) diameter corrugated plastic drainage tubing (D), or 200 mm (8 in.) diameter smooth-wall plastic, clay or concrete drain tile (E).

Figure 2 can also be used to find solutions for drainage coefficients that aren't shown.

For example, a design with a coefficient of 25 mm (1 in.)/day is approximately double the 12 mm (½ in.)/day coefficient used above. In this case, double the drainage area to 20 ha (50 ac), and use a straight edge from 0.2 on (A) through 20 ha (50 ac) on (C) and read the required drain diameter in (D) or (E). To obtain solutions for other drainage coefficients, use the following conversion factors:

Drainage Coefficient mm (in.)	Factor
9 (⅜)	1.5 x area
12 (½)	1.0 x area
20 (¾)	0.75 x area
25 (1)	0.50 x area
35 (1½)	0.33 x area

Graphical Method (Figures 3, 4, 5 and 6)

An alternative method for selecting the proper diameter of the main drain gives additional information on pipe flow velocity and drain discharge which may be useful in the design. Use this method for large diameter pipe and areas not included in Figure 2.

Enter Figure 3 using the drainage area, in hectares, and move vertically to the diagonal line representing the appropriate drainage coefficient. Move horizontally to the left to obtain the drain discharge, L/s.

Enter the left side of Figure 4 for corrugated plastic drainage pipe, or Figure 5 for clay or concrete drain tile, or Figure 6 for smooth-wall plastic using the drain discharge determined from Figure 3. Move horizontally to the right until to intersect the vertical line indicating the grade of the drain. This intersection determines the diameter of the pipe and the velocity of flow in the drain when running full.




Example 1: A main drain on a grade of 0.2% (0.2 m/100 m or 0.2 ft/100 ft) is used as an outlet for 10 ha (25 ac) of land at a drainage coefficient of 12 mm (½ in.)/day.

An area drained of 10 ha (25 ac) and a drainage coefficient of 12 mm (½ in.)/day in Figure 3 produces a design discharge of 14 L/s. Enter Figure 4 at 14 L/s and move to the right to the grade 0.2, the required diameter of corrugated plastic drainage tubing is 250 mm (10 in.). Similarly, enter Figure 5 at 14 L/s and move to the right to 0.2, the required diameter of clay or concrete pipe is 200 mm (8 in.). Figure 6 yields the same value for smooth-wall plastic pipe.

Example 2: A subsurface drainage system is planned for a 20 ha (50 ac) parcel of land for cash crops. A blind inlet is installed in a 1 ha (2.5 ac) depressional area. In addition, a catchbasin at the field boundary intercepts surface water draining from 4 ha (10 ac) of neighbouring property. Assuming a grade of 0.5%, what size of main is required?

Using the method outlined in Section 2.10, determine the total design flow using Figure 3. The design flow for the main is composed of:

- 20 ha @ 12 mm/day = 28 L/s
- 1 ha @ 15 mm/day = 2 L/s
- 4 ha @ 25 mm/day = 12 L/s

The total design flow for the main is 42 L/s. Enter Figure 4 at 42 L/s and move to the right to the grade 0.5%, the required diameter of corrugated plastic drainage tubing is 300 mm (12 in.). Similarly, enter Figure 5 at 42 L/s and move to the right to 0.5% grade, the required diameter of clay or concrete pipe is 250 mm (10 in.). Figure 6 yields the same value for smooth-wall plastic pipe.

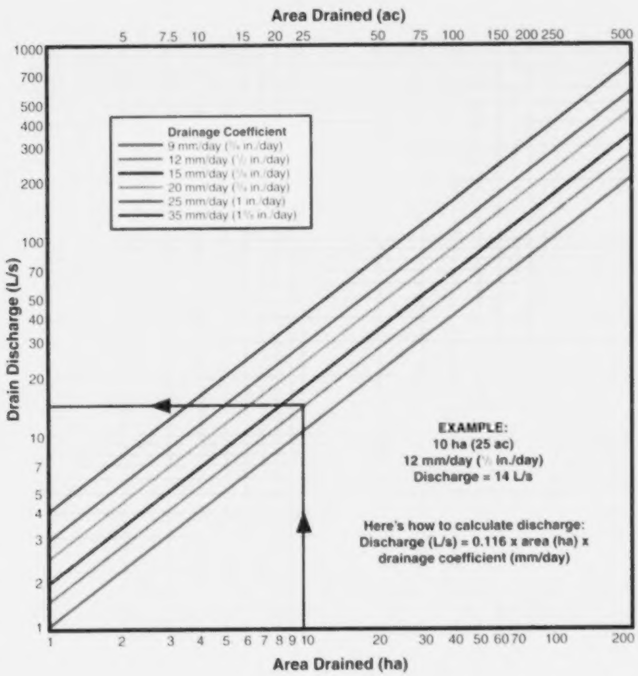


Figure 3. Drain Discharge from Area Drained

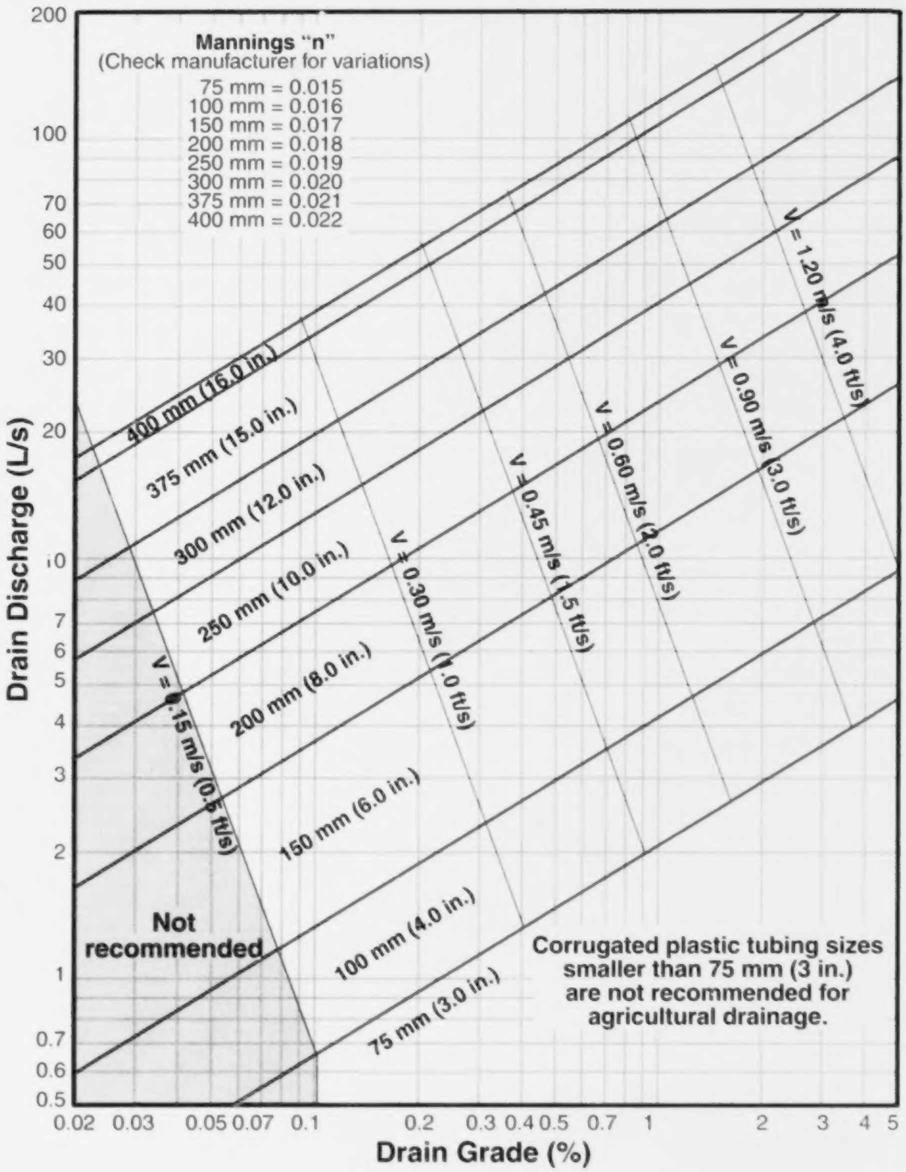
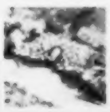


Figure 4. Drain Diameter of Corrugated Plastic Drainage Tubing



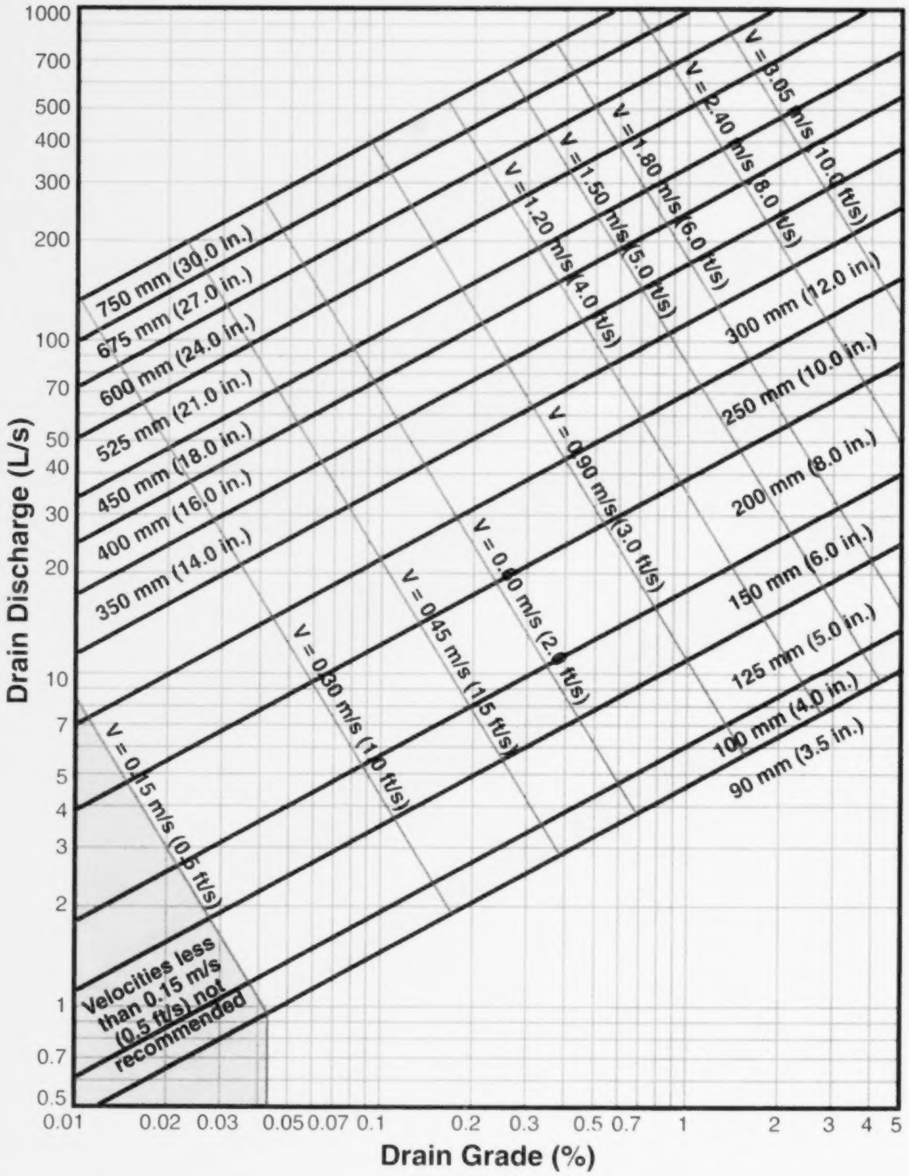


Figure 5. Drain Diameter of Concrete and Clay Pipe

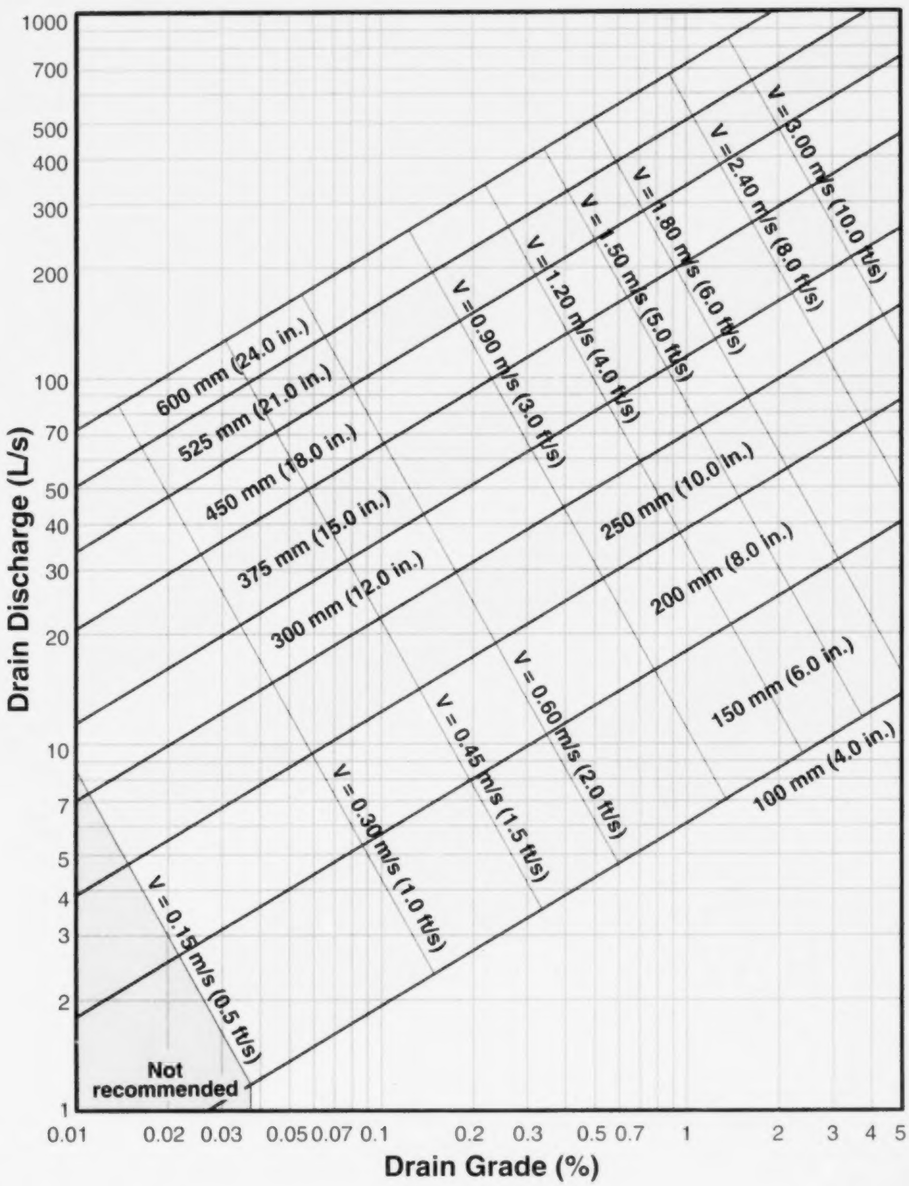


Figure 6. Drain Diameter of Smooth-wall Plastic Pipe

The Manning pipe roughness factors used to calculate Figure 5 for concrete and clay pipe and Figure 6 for smooth-wall plastic pipe is 0.011. Figure 4 (corrugated plastic pipe) is constructed using a variable Manning pipe roughness. These are:

75 mm	(3 in.)	‣ 0.015
100 mm	(4 in.)	‣ 0.016
150 mm	(6 in.)	‣ 0.017
200 mm	(8 in.)	‣ 0.018
250 mm	(10 in.)	‣ 0.019
300 mm	(12 in.)	‣ 0.020
375 mm	(15 in.)	‣ 0.021
400 mm	(16 in.)	‣ 0.022

Source: Friction factors for corrugated plastic drainage pipe, Ross W. Irwin and Jiri Motycka, Journal of Irrigation and Drainage, A.S.C.E., Vol. 105, No. 1, 29 - 36, 1979.

The required diameter D (mm) for larger drain pipe can be determined from the equation:

$$D = 122.6\,(D_c A n)^{0.375} s^{-0.1875}$$

D_c = drainage coefficient (mm)
A = drained area (ha)
n = Manning pipe roughness coefficient
s = grade in %

The flow rate of large diameter corrugated plastic tubing can be estimated from the equation:

$$Q = 7.56\,D^{2.5}\,s^{0.5}(R/\lambda)^{0.31}$$

Q = pipe discharge (m^3/s)
D = internal pipe diameter (m)
s = unit gradient (m/m)
Ï = spacing between corrugations (m)
R = internal pipe radius (m)

Source: Corrugated Pipeflow Rate from Pipe Geometry, R.W. Irwin, ASCE Journal, Irrigation, & Drainage, 110: #2, 237-241, June 1984.

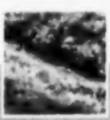
The minimum pipe size for a small diameter main drain is 100 mm (4 in.). When this size is used as a main or submain drain, use 75% of the design capacity from Figures 4, 5 or 6. This reduction in capacity takes potential losses into account from sediment accumulation, drain connection roughness, etc.

2.12 Seepage Interception

An interceptor drain should cross the slope and intercept seepage water before water reaches the ground surface. Locate the drain up the slope from the seepage area, perpendicular to the flow path and approximately at the impervious layer where groundwater flows.

Place drains closer together and deeper in the wet area when the source of seepage water is vertically from below. Also consider installing a cross-drain between adjacent lateral drains in the wet area, with gravel backfill.






Determine the size and capacity of single random interceptor drains from Figures 4, 5 or 6 when designed for the inflow rates shown in Table 5.

Table 5. Inflow Rate to Interceptor Drains

Soil Texture	Inflow Rate per 100 m of Drain (L/s)[1,2]
Coarse sand and gravel	1.0-3.5
Sandy loam	0.5-1.5
Silt loam	0.2-0.75
Clay and clay loam	0.02-0.50

[1] Discharge of flowing springs, or direct entry of surface water through a surface inlet or blind inlet, must be added to the above. Such flows should be measured or estimated.
[2] Inflow rates for interceptor lines on sloping land should be increased by 10% for land slopes 2 to 5%, by 20% for slopes 5 to 12%, and by 30% for slopes over 12%.

Source: Drainage by the Interception Method, E.W. Gain, US-SCS 1951, NA-ASAE.

To determine the total inflow for an interceptor drain from Table 5, enter the left side of Figures 4, 5 or 6 with this value. Move horizontally to the right to intersect the grade of the drain – this point locates the diameter of pipe required.

For example, assume the inflow rate from a sandy loam soil is 1.50 L/s. The design discharge from a 500 m (1,640 ft) drain across a slope of 7% is 1.50 x (500 ÷ 100) = 7.5 L/s for a land slope less than 2%. This value must be increased by 20% for a 7% land slope, i.e. 7.5 x 0.20 = 1.5 L/s. That makes the design flow 7.5 + 1.5 = 9.0 L/s. If the grade on the drain is 0.5%, Figure 4 shows the required diameter of corrugated plastic drainage tubing is 200 mm (8 in.).

2.13 Minimum Diameter of Lateral Drains

The minimum recommended diameter of pipe for lateral drains is:

- 100 mm (4 in.) for corrugated plastic tubing
- 90 mm (3.5 in.) for clay tile
- 75 mm (3 in.) when grade produces clear water velocity >0.15m/s (0.5 ft/s) (see Table 7)

Although generally not recommended, use 50 mm (2 in.) corrugated plastic tubing in special circumstances and certain soil conditions (e.g. S1 soils, sports fields, lawns, etc.).

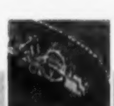
2.14 Length of Lateral Drains

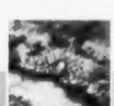
The maximum length of lateral drain is restricted by the area that causes the drain to run full. Calculate by entering Figures 4, 5 or 6 with the grade of the drain and determine the discharge.

Use Figure 3 to determine the drained area, in hectares (ha), for a pre-selected drainage coefficient. Calculate the maximum length of drain, L, (m) from the equation. S is the lateral drain spacing.

Metric measurement: L (m) = area (ha) x 10,000/S (m)
Imperial measurement: L (ft) = area (ac) x 43,560/S (ft)

The minimum length of lateral drain is usually greater than two times the drain spacing. To calculate the amount of tile needed to drain an area, see Table C1.



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2.15 Depth and Cover of Lateral Drains

Drain depth is the distance from the ground surface to the bottom of the trench. Drain cover is the distance from the ground surface to the top of the drain pipe (see Figure 7).

Many factors impact drain depth and it is important to examine the soil profile before selecting the depth of drains (see Figure A1). For recommended ranges of drain depth see Table 3 or 4. When designing a system, keep in mind that installation cost often increases with depth of drain.

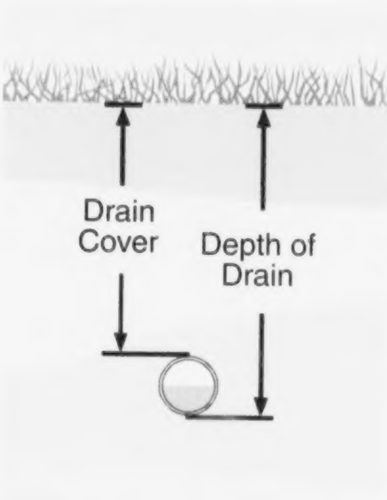


Figure 7. Drain Depth and Cover

Drain depth is affected by:

- available outlet depth
- minimum root zone required for shallow rooted crops
- soil physical properties
- protection of pipe from damage by farming operations
- stoniness of soil profile
- spacing of lateral drains

In medium to coarse sandy soils, keep lateral drains no deeper than 750 mm (30 in.).

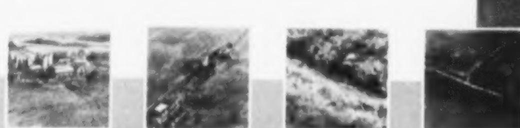
Minimum cover for main drains is 600 mm (24 in.) for pipe diameters up to and including 150 mm (6 in.), and 750 mm (30 in.) for pipe diameters 200 mm (8 in.) or greater.

Minimum cover for lateral drains is 600 mm (24 in.), to protect a drain from breakage by farm machinery. Under the following conditions, 500 mm (20 in.) cover is acceptable provided lateral spacing is adjusted and heavy equipment doesn't traverse drain lines:

- slowly permeable soils
- where rock, stones, sand or dense soil prohibit greater depth
- depressional or impounded areas with an outlet problem
- where outlet depth is limited and cannot be improved
- where drains are to be used for sub-irrigation

If this minimum cover can't be obtained, use continuous high strength rigid perforated pipe, filling the area with earth until sufficient cover is provided.

Pipe that meets the standards in Section 6 will withstand earth pressure up to 2 m (6.5 ft) deep if installed in open or closed trenches with a width no greater than 500 mm (20 in.). Drains installed by conventional agricultural drainage machines in Ontario don't normally exceed these maximum cover limits. If very deep and wide trenches are used, seek advice from a drainage engineer familiar with the design of deep drains.



Install drains so the dead load of the soil, and impact and live loads of machinery, doesn't exceed the minimum strength of the drain pipe. Table 6 shows the percent of live and impact loads transmitted to the drain pipe for a vertical wall trench.

Table 6. Percent of Applied Surface Load on Buried Pipe

	Trench Width at Top of Pipe			
Cover	**300 mm** (12 in.)	**600 mm** (24 in.)	**900 mm** (36 in.)	**1,200 mm** (48 in.)
600 mm (24 in.)	8%	14%	18%	21%
900 mm (36 in.)	4%	8%	11%	14%
1,200 mm (48 in.)	3%	5%	7%	9%
1,500 mm (60 in.)	2%	3%	5%	6%

2.16 Grade

Install subsurface lateral drains as close to uniform depth as topography permits, and maintain continuous grades. In design, the grade of the drain is assumed to be parallel to the hydraulic grade line. For design purposes, assume the hydraulic grade line remains within the drain, i.e. the drain doesn't run under pressure. On flat land, make grades as great as possible without sacrificing drain cover to obtain it (see Section 2.15).

Minimum Grade

Minimum grades are shown in Table 7. Select a grade, where possible, to produce a non-silting velocity of 0.45 m/s (1.5 ft/s). Where this isn't possible, include silt basins in the system design. Where sedimentation isn't a hazard, select a minimum grade for a velocity of 0.15 m/s (0.5 ft/s). Avoid reverse grade, and interpolate between ranges provided.

Table 7. Recommended Minimum Grade

Drain Diameter	Clear Drains* Not Subject to Sediment		Drains Subject to Sediment	
	Smooth Pipe**	**Corrugated Pipe**	**Smooth** Pipe**	**Corrugated Pipe**
1	2	3	4	5
75 mm (3 in.)	0.08%	0.10%	0.48%	1.0%
100 mm (4 in.)	0.05%	0.08%	0.32%	0.7%
150 mm (6 in.)	0.025%	0.06%	0.18%	0.5%
200 mm (8 in.)	0.02%	0.04%	0.12%	0.4%
250 mm (10 in.)	0.018%	0.035%	0.09%	0.3%
300 mm (12 in.)	0.012%	0.03%	0.07%	0.25%

*The grades in columns 2 and 3 provide a minimum velocity of 0.15 m/s (0.5 ft/s) at full flow and in column 4 and 5 provide 0.45 m/s (1.5 ft/s) at full flow.
**Well-aligned clay, concrete and plastic smooth wall pipe.

2 Planning and Design




Maximum Grade

Maximum grades are shown in Table 8. These are for main drains, flowing full but not under pressure, and should not produce velocities exceeding those listed.

Table 8. Maximum Permissable Velocity of Flow in a Drain Pipe

Soil Texture	Velocity m/s (ft/s)
Sand – sandy loam	1.0 (3.3)
Silt – silty loam	1.5 (5.0)
Silty clay loam	1.75 (5.75)
Clay and clay loam	2.0 (6.6)
Coarse sand and gravel	2.5 (8.2)

When these velocities are exceeded, take protective measures to prevent soil movement. Velocity is determined from Figures 4, 5 or 6. Interpolate between ranges for other soils. For effective drainage, the maximum grade of lateral drains should not exceed 2%.

Design of Main Drains on Steep Slopes

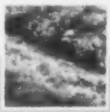
- A steep slope is one where a partially filled drain pipe has a Froude Number ($F = V/(gD)^{1/2}$ greater than 1, where $g = 9.8$. The minimum velocity, $V = 3.13\ D^{1/2}$, where V is in m/s and D is the pipe diameter in metres.
- Design short lengths of main drain on steep slopes to flow half-full.
- When the drain flows half-full, and the grade is 1 to 4% in sandy soil, 2 to 6% in silt or loam soil, or 6 to 15% in clay soil, use continuous non-perforated pipe, and wrap and protect drain tile joints. Tamp soil firmly around the drain.
- When the drain flows full, and the grade is over 1% in sandy soil, over 2% in silt or loam soil, and over 6% in clay soil, use continuous non-perforated pipe.
- Install a breather at the top of steep sections to prevent negative pressure in the drain (see Section 3.10).
- Install a relief well at the bottom of steep sections unless the drain discharges directly into an open ditch (see Section 3.10).

2.17 Drainage System Pattern Design

A subsurface drainage system design provides uniform drying of the field surface so crops aren't harmed by excess water and field operations can take place. Topography and physical field obstructions determine the drain layout, and include location of pipelines, hydro towers, ditches, stones, barn and manure storages. Keep the lateral drain layout simple to minimize installation cost and maintenance, while achieving drainage objectives.

Traditional drain patterns or layouts are systematic or comprehensive, random or interceptor. Uniform slopes are most effectively drained by a system of regularly spaced parallel drains connecting into a main drain. Fields with complex slopes are also systematically drained with more sub-mains and main drains. On sloping land, lateral drains are positioned across the slope to intercept the natural downslope movement of water.






Systematic Drain Patterns (see Figure 8A)

- Provides a consistent level of drainage over the area.
- Historically, lateral drain patterns were typically gridiron at right angles to field boundaries.
- Current systems are designed at an angle to the field boundary and across the slope or field working pattern.

Herringbone Patterns (see Figure 8B)

- When used on sloping land, require more connections, higher cost and shorter lateral drains.

Random Pattern Layout (see Figure 8C)

- Suitable for undulating or rolling land with isolated wet areas.
- Lay main drain in the low area.
- Install a few lateral drains and spur drains in low areas between hills.
- Size and locate main drain to include any future growth to this type of system.

Double Main Pattern (see Figure 8D)

- Use when there is a stream, farm lane, pipeline or other obstruction.
- The cost of a second main drain can be a disadvantage.
- Use interceptor drains to intercept the flow of water before it exits on the soil surface, usually side hill seepage (see Section 2.12).

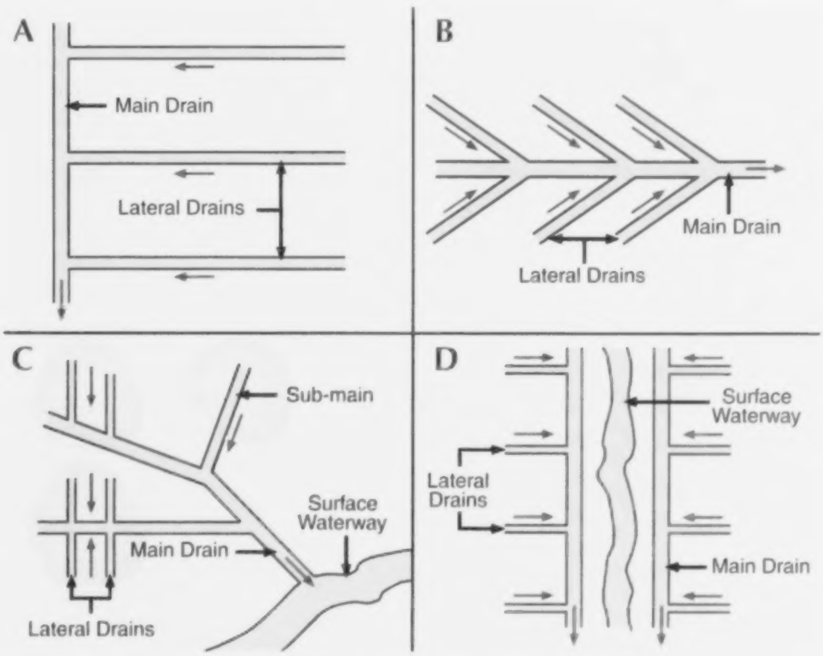
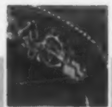
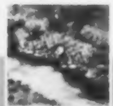


Figure 8. Basic Patterns for Subsurface Drainage Systems

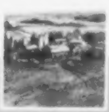
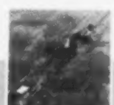
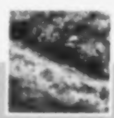


2.18 Initial Investigative Procedures

- Walk the area to determine possible outlets, low problem areas, high ridges, and the history of cropping practices.
- Evaluate the soil profile, determine landowner's assessment of drainability and identify any construction problems such as very fine sand, gravel, large stones, shallow bedrock, iron ochre or high water table.
- Survey the area and draw a topographic map at a large enough scale for planning, showing obstructions such as fences, trees, buildings, utilities and outlets.
- Select the average depth of lateral drains from Table 2 and 3, based on the rooting depth of crops, available outlet elevation, the elevations of key problem areas and Section 2.15.
- Select the spacing width for lateral drains based on Table 2 and 3, and discussions with the landowner.
- Allow for possible sedimentation at the outlet when selecting the outfall elevation, refer to Section 7.17 and Figure 10 and 11.
- Check the legal status of the outlet. Contact the local municipality for municipal drains.
- Check for utility easements and obtain necessary permits.

2.19 Additional Considerations

- Use as few outlets as possible to reduce potential future problems.
- Take advantage of surface slopes and maintain as uniform a depth of drain as the land surface permits.
- Design the system with long lateral drains and short main drains for economics. Be sure long lateral drains are not too deep.
- When feasible, lay out lateral drains at an angle to the direction of surface water flow.
- When feasible, lay out lateral drains at an angle to the normal farming pattern.
- On flat land (0.1% or less) plan lateral drains in the direction of greatest surface slope.
- Follow the general direction of a natural waterway with mains and submain drains. Where possible, offset drains from the lowest elevation to avoid reduced cover and erosion damage.
- Control water table levels deep enough to provide optimum root development for the deepest rooting crop grown.
- Obtain the diameter of the main drain and long lateral drains from Section. 2.11 – changing pipe causes large changes in capacity.
- Use a direct or indirect connection to connect existing functioning subsurface drains to the new system.
- Do not connect drains that carry polluted water.
- If needed, drain small areas of wetter land with stub drain lines at closer spacing.
- Use a cut-off at the high end of fields so surface water won't run onto the field.
- Avoid deep cuts and cut downs.
- Check that the outlet is in the most suitable location.
- The drainage effect of a lateral drain at the upper end is equivalent to one-quarter of the drain spacing.


- At the upper end of the laterals: If using a header tile, locate it no more than one half of the drain spacing away from the ends of the lateral drains (see Figure 9). If a header tile isn't used, end laterals no further than one-quarter of the drain spacing from the field boundary. Other techniques can be used to achieve the same drainage objective.
- Position header tile no closer than 3 m (10 ft) from the field boundary.

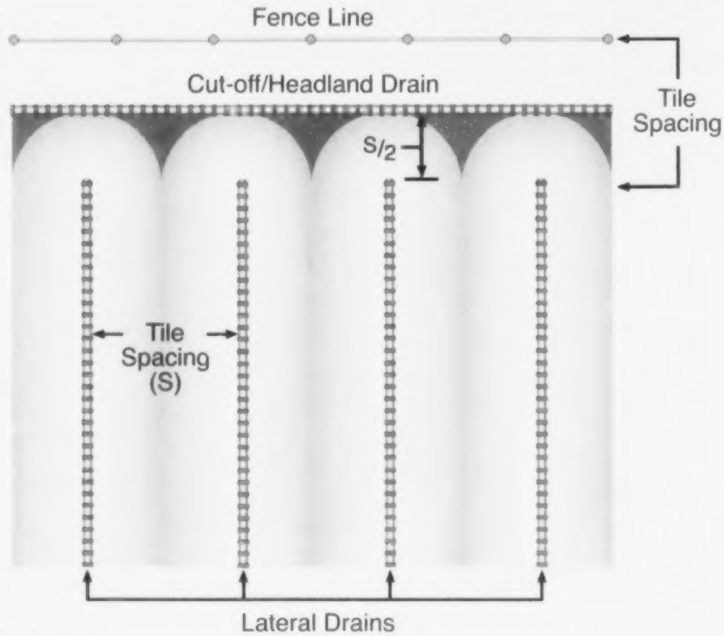


Figure 9. System Layout at Upper End of Laterals

3. Drainage System Structures

3.1 General

A drain system structure is an auxiliary part to a subsurface drainage system. The structure must not unduly impede the flow of water in the drainage system, and its capacity must not be less than the drains feeding into or through them. Typical drainage structures are:

- outfalls
  - end pipes
  - headwalls and rock chutes
  - drop pipe structures
  - vegetation establishment
- surface water inlets
  - riser inlets
  - ditch inlets
  - silt basins, catch basins, sediment traps
  - blind inlets
- junction boxes
- relief wells and breathers
- end caps and plugs
- siphons
- drain crossings
- inline flow control devices

Determine the number, type and size of structures during the design of the drainage system. Consider soil borings to ensure a solid foundation for structures.

3.2 Outfall

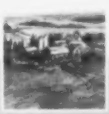
The outfall is the most important part of a drainage system and must be properly built and maintained. For ease of maintenance, fewer outfalls are better for the drainage system. When designing the system, consider potential damage and legal action that could result from poorly designed outlets. Protect the drain system against erosion from turbulence and high velocities created near outfalls, surface inlets or similar structures. Be sure to protect shallow subsurface drains near the outlet from excessive machinery loads and farm work.

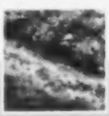
End Pipes

Protect pipes discharging into ditches or watercourse from erosion and undermining. Use a length of continuous rigid, non-perforated pipe for an end pipe. Protect end pipes for plastic tubing drainage systems against weather, fire and animal damage, and crushing. Standard corrugated plastic tubing is not satisfactory for an end pipe.

End pipes are joined to drain tile by sleeve joints or butt joints.

- ***Butt Joints:*** The inside diameter of the end pipe must be equal to or larger than the inside diameter of the drain pipe, and not exceed the outside diameter of the drain pipe by more than 25 mm (1 in.). Wrap the joint with a material or seal to ensure soil doesn't enter the joint.






- ***Sleeve Joints:*** The drain tile must be inserted a minimum of 300 mm (1 ft) into the end pipe. The inside diameter of the end pipe should not exceed the outside diameter of the drain pipe by more than 50 mm (2 in.). If the inside diameter of the end pipe is less than 25 mm (1 in.) larger than the outside diameter of the drain tile, no wrapping is required. If the inside diameter of the end pipe is more than 25 mm (1 in.) larger than drain tile, wrap the joint.

The minimum dimensions of end pipe are shown in Table 9. Embed the pipe in the bank to provide support, and install the end pipe as soon as the drain is constructed.

Table 9. Dimensions of End Pipe

Nominal Drainpipe Diameter mm (in.)	End Pipe Dimensions			
	Minimum Diameter mm (in.)		Minimum Length mm (ft)	Maximum Cantilever mm (in.)
	Butt Joint	Sleeve Joint		
100 (4)	100 (4)	Maximum Outside Diameter of Drainpipe + 50 mm (2 in.)	3,000 (10)	400 (16)
150 (6)	150 (6)		3,000 (10)	600 (24)
200 (8)	200 (8)		3,000 (10)	600 (24)
250 (1)	250 (10)		3,600 (12)	600 (24)
300 (12)	300 (12)		3,600 (12)	800 (32)
350 (14)	350 (14)		4,800 (16)	800 (32)
400 (16)	400 (16)		5,400 (18)	800 (32)
450 (18)	450 (18)		6,000 (20)	1,000 (40)

Attach a hinged grate or rodent guard to the end pipe at time of installation. Grate openings must not exceed 25 mm (1 in.). The design of the grate must permit removal of debris.

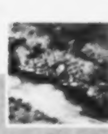
Allow a minimum freeboard of 300 mm (12 in.) in the end pipe above the normal ditch water level, and consider future sedimentation in the outlet ditch.

Use flush mounted end pipes where there is sufficient protection from erosion (see Figure 10). This type of end pipe is less susceptible to ice damage compared to cantilever style end pipes.

Use cantilever style drain end pipes where sufficient erosion control protection has been incorporated (see Figure 11). This type of end pipe is more susceptible to ice damage than flush mounted outfalls.

Markers should be used to indicate the location of each end pipe.



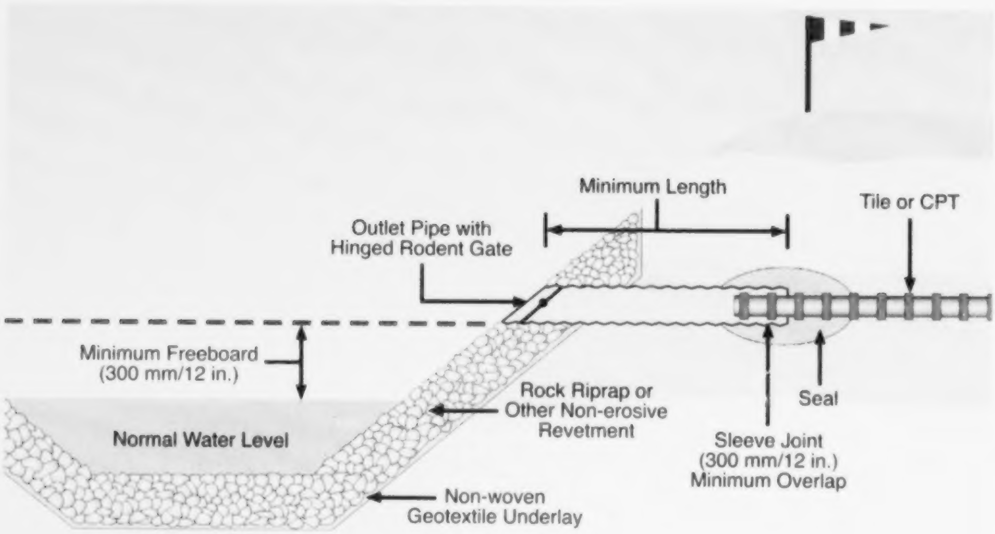


Figure 10. Flush Mounted End Pipe

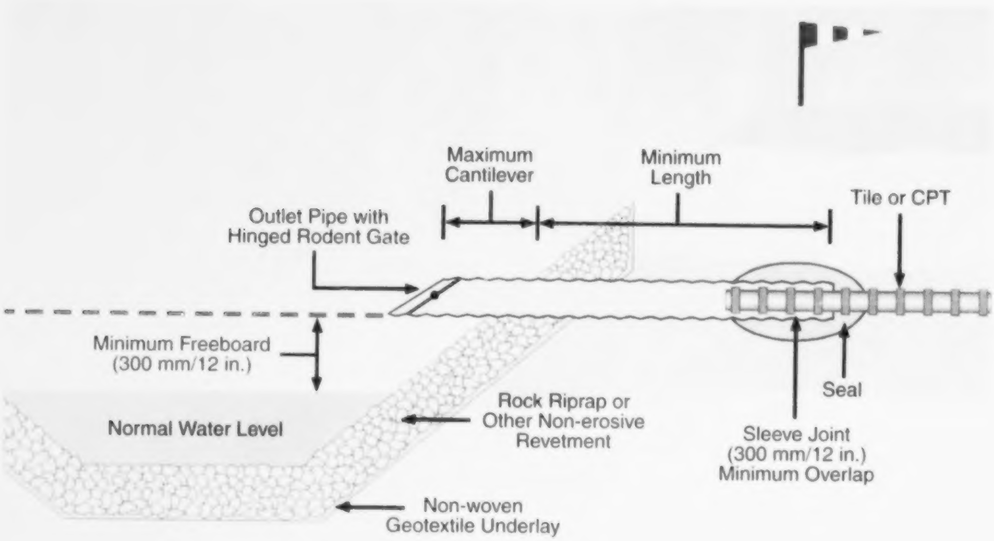
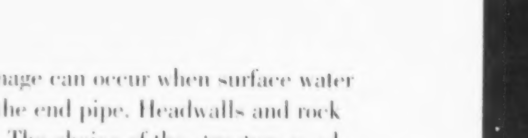


Figure 11. Cantilever Style End Pipe

Headwalls and Rock Chutes

Unless precautions are taken, stream and ditch bank damage can occur when surface water enters the receiving watercourse at the same location as the end pipe. Headwalls and rock chutes structures provide protection against this damage. The choice of the structure used depends on the local site characteristics and availability of materials.



- ***Headwalls:*** A headwall protects the end pipe and receiving stream from erosion, and must be adequate strength and design to avoid failure. Headwalls are used infrequently, but use with a splash plate when necessary (see Figure 12). Construct headwalls of any durable material such as concrete or bagged concrete.

- ***Rock Chutes:*** Rock chutes work similar to headwalls and require more space because of the material used (see Figure 13).

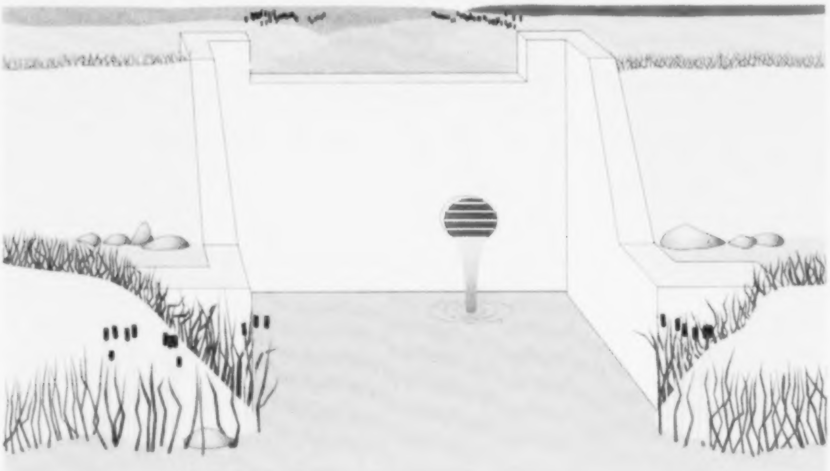


Figure 12. Headwall Outlet

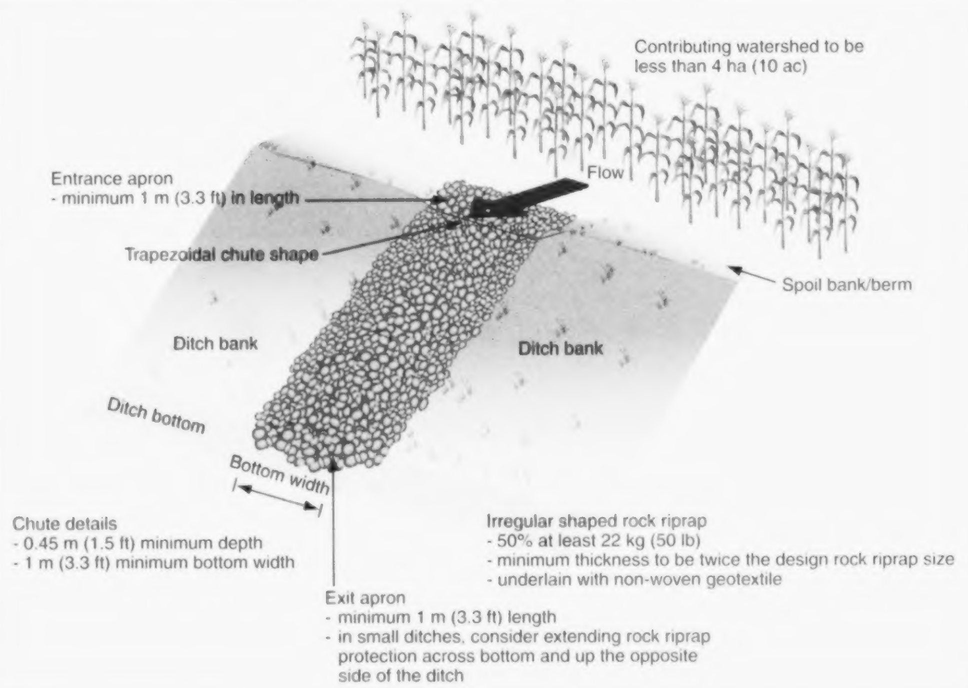


Figure 13. Rock Chute Outlet

Drop Pipe Structures

Drop pipes are erosion control structures that form part of the outlet for a drainage system, or are located at gullies where drainage water discharges. Specialized design and construction is often required (by consultants) when using drop pipe.

Vegetation Establishment

Establishing permanent vegetation in any disturbed area at the outlet, as soon as possible after construction, will minimize erosion and environmental concerns. Landowners and contractors must determine who is responsible for this practice.

3.3 Surface Water Inlets

Surface water inlets allow surface water to enter subsurface drains. This is an expensive practice and inlets are only recommended for draining low areas where it's not feasible to install a surface drainage system. Where feasible, design open channels and waterways in conjunction with subsurface drainage systems to carry as much of the surface runoff as needed (see Figure 14).

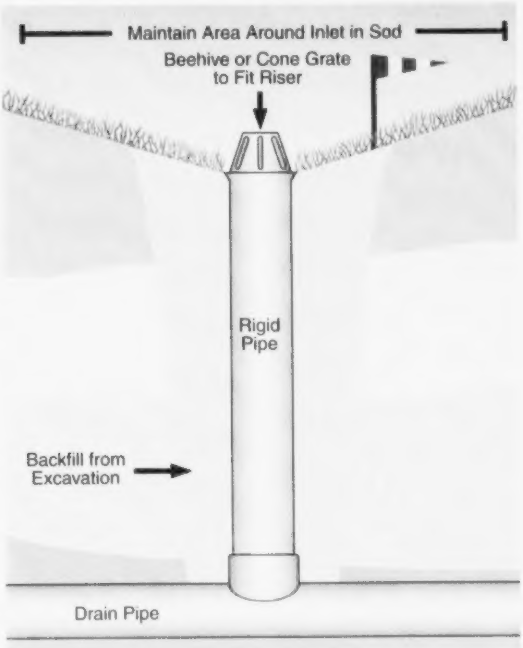


Figure 14. Surface Water Inlet

Installation Considerations

- If used on land intended for manure and biosolids application, consider the impact on the drainage system and to the environment.
- Use only where surface drains are not practical because surface inlets often present a maintenance problem.
- Surface inlets may be needed to help remove surface water concentrated in depressions, where specialized crops are grown, or when routing surface water underground from higher areas to prevent flow across a flat cultivated area.

- *Headwalls:* A headwall protects the end pipe and receiving stream from erosion, and must be adequate strength and design to avoid failure. Headwalls are used infrequently, but use with a splash plate when necessary (see Figure 12). Construct headwalls of any durable material such as concrete or bagged concrete.

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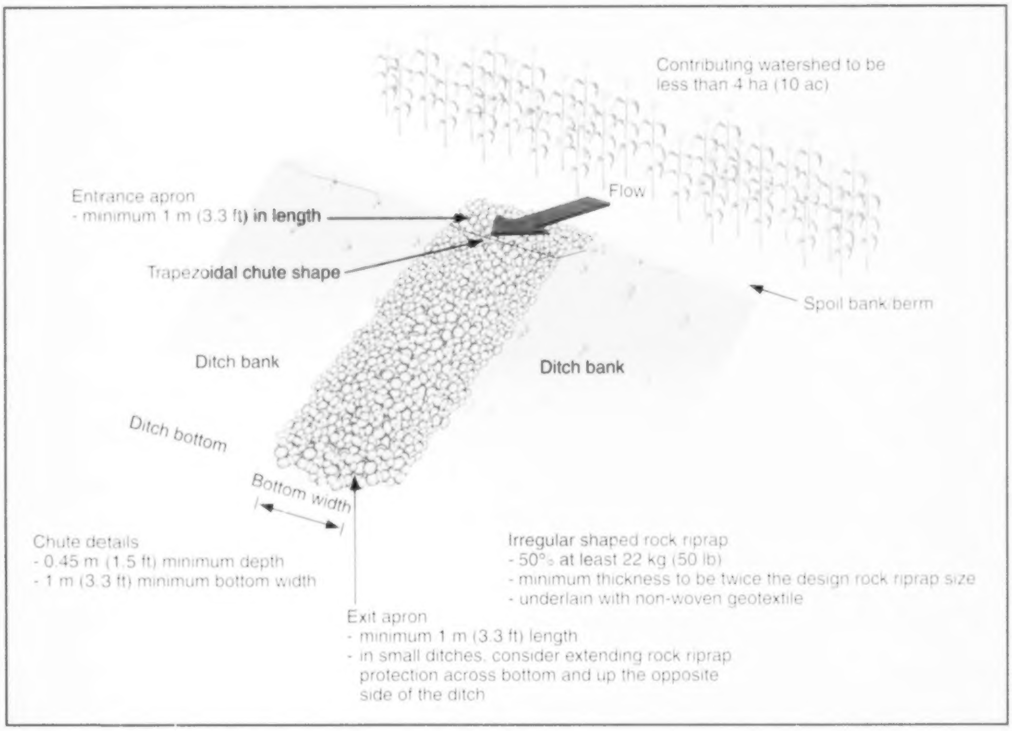
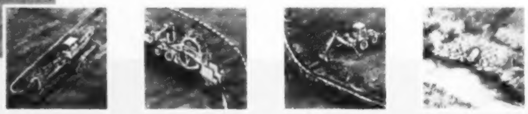


Figure 13. Rock Chute Outlet



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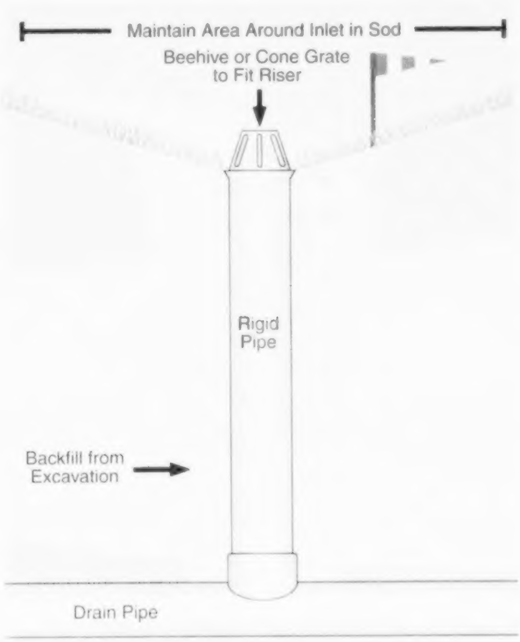

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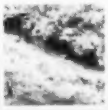



- Determine capacity needed for surface water inlets by hydrologic procedures for the drainage area served by the inlet.
- Surface water inlet structures should exclude floating debris, field-applied manure and stop the entry of rodents.
- Provide a total flow restrictor device with each surface water inlet structure.

Example applications or locations of surface inlets are:

- A fence line or other boundary where the subsurface system picks up surface water from an adjoining area.
- A ditch where water from the ditch enters a subsurface system.
- A depressional area where specialized crops grown are susceptible to water damage and require the designed removal of surface water.
- A depressional area with low soil permeability where a blind inlet won't have sufficient capacity or isn't appropriate for the situation.
- An erosion control structure where surface waters are diverted to a subsurface system to prevent erosion from the concentrated overland flow. A floodwater storage system is often incorporated into the design. This type of system is usually referred to as a water and sediment control basin.

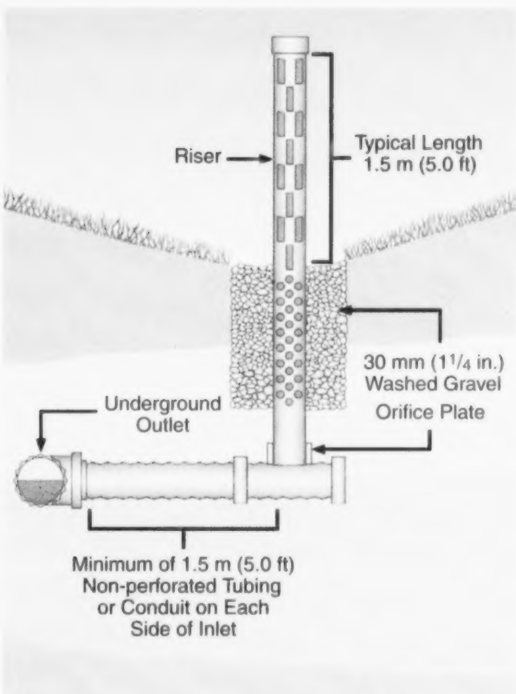


Figure 15. Offset Riser Inlet

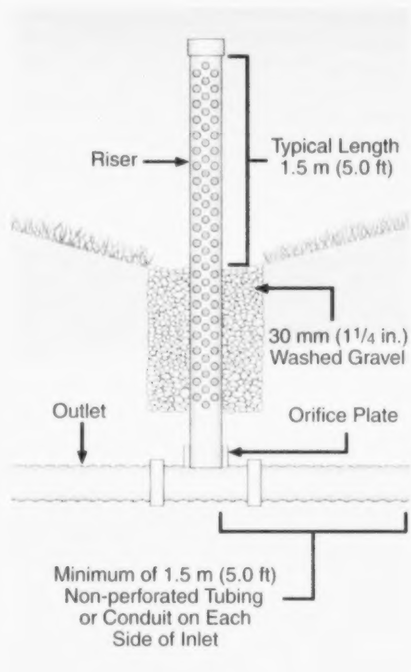
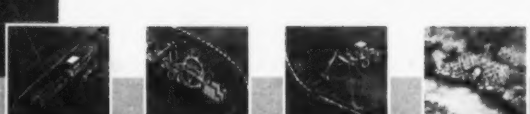


Figure 16. On-line Riser Inlet



Riser Inlets

Use riser inlets for small flows, especially for potential trash problems. To prevent trash from plugging the inlet, be sure the capacity of the holes isn't the limiting factor.

Offset riser inlets from the receiving pipe by 1,500 mm (5 ft) using a non-perforated conduit (see Figure 15). If the riser inlet is installed on-line, use solid tubing on either side of the inlet (see Figure 16). Use riser inlets that are durable, structurally sound, and resistant to fire and rodent damage. Vertical pipes with holes or slots are used as inlets.

To act as a catchbasin, the capacity of a surface water inlet must not be less than the maximum design flow in the drain line. Install a flow control device (e.g. orifice type flow control) in the base of the riser pipe, if necessary, to control the volume of water entering the subsurface drain.

The capacity of an orifice plate can be calculated from the following two equations:

- The design head on a riser inlet orifice plate is $H = 0.7d_1 + d_2$

d_1 = depth of the low area above the design surface elevation to the top of the berm
d_2 = depth to the orifice plate below the ground level of the low area

- The discharge, Q, of a riser outlet is $Q = 2.66\ A\ H^{1/2}$

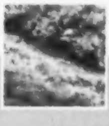
$Q = m^3/s$
H (head on orifice plate) = m
A (area of orifice) = m^2

For example, a 50 mm (2 in.) orifice plate is installed in a riser inlet, connected to a 100 mm (4 in.) tile at a 0.4% slope. The dimension from the orifice plate to ground level, d_2, is 0.6 m (2 ft). The dimension from ground level to the top of the berm, d_1, is 0.9 m (3 ft). The head, H, on the orifice is $(0.7 \times 0.9) + (0.6) = 1.23$ m (4 ft). The area of the 50 mm (2 in.) orifice is 0.002 m^2 (3.1 in^2). The discharge, Q, into the drain line is $Q = 2.66 \times 0.002 \times \sqrt{1.23} = 0.006$ m^3/s (0.21 ft^3/s).

From Figure 3, a 100 mm (4 in.) drain at a grade of 0.4% has a capacity of 2.8 L/s or 0.0028 m3/s (0.1 ft^3/s). The size of the drain pipe controls the flow and an orifice is not required. This means, however, the inlet will delay flows from higher elevations.

As a variation of a riser inlet, create a surface inlet flush to the ground surface by excluding the above-ground portion of the riser pipe and replace with a grate (cone or beehive) to prevent entry of debris into the underground system. Install a marker to identify the location.





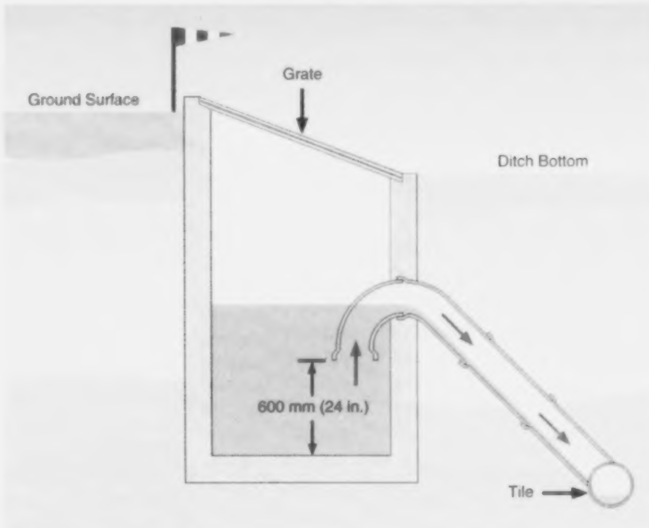



Figure 17. Ditch Inlet

Ditch Inlets

Ditch inlets permit surface water in a ditch to enter a subsurface drainage system (see Figure 17).

- The grade of the ditch has a negligible effect on inlet capacity.
- The crest of the inlet is the same elevation as the ditch bottom.
- Longitudinal bars are spaced on the trash grate to prevent debris entry.
- Install the grate at an approach slope of 1:1.
- Install a trash fence upstream from the inlet.
- Estimate the required horizontal width of the unobstructed inlet from Figure 18.

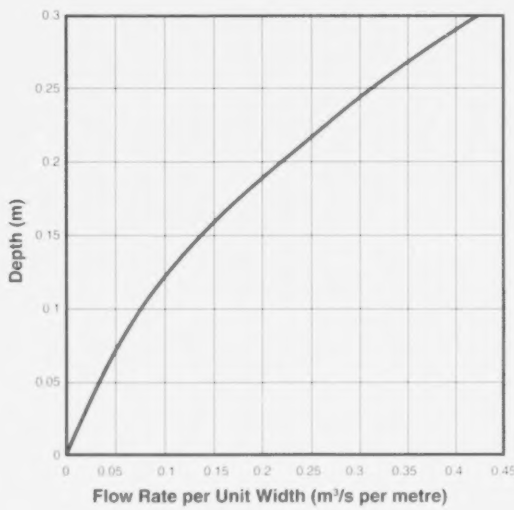


Figure 18. Ditch Inlet Design Chart

For example, assume a ditch has a design flow of 0.15 m^3/s (5.3 ft^3/s) and the design head on the inlet is 0.20 m (0.66 ft). Enter Figure 18 at 0.20 m (0.66 ft) depth of flow and determine the flow rate per unit width of inlet is 0.22 $m^3/s/m$ (2.37 $ft^3/s/ft$). The design width of the inlet is $0.15 \div 0.22 =$ 680 mm (2.23 ft). The width may be increased by 50% to 1.02 m (3.35 ft) to allow for obstruction by corn leaves, etc.

Silt Basins

This type of structure is used as a settling chamber to separate sediment from water and as an access inspection point to the drainage system (see Figure 19).

- Use down grade from where a drain passes through a problem sandy area.
- Locate, where possible, at permanent fences or in non-cultivated areas.
- If used in cultivated areas, install with the top of the structure a minimum of 450 mm (18 in.) below the ground surface, and adequately construct to support any load placed on it by farming equipment.
- Clearly identify the location of a silt basin either on-site with a marker, or record through details on drawing, GPS location coordinates, etc.

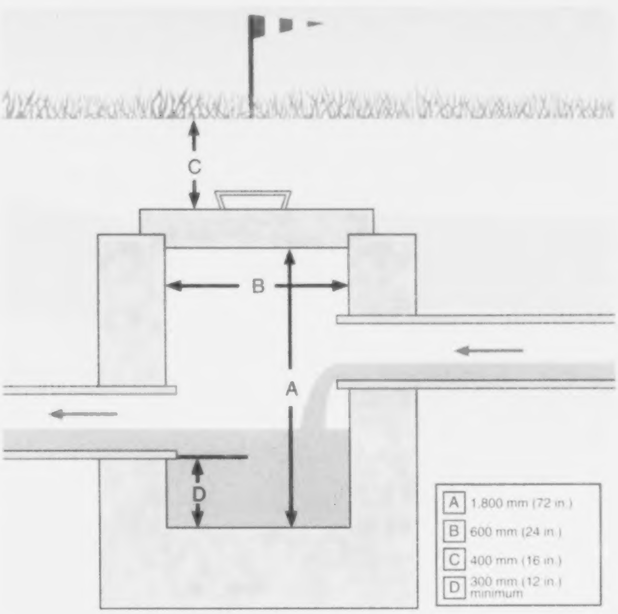


Figure 19. Silt Basin

Base the size of the silt basin on accessibility for maintenance.

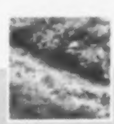
- circular structures – minimum diameter of 750 mm (30 in.)
- square or rectangular structures – minimum dimension of 600 mm (24 in.)
- depth of sediment trap – minimum of 300 mm (12 in.), increase for longer intervals between maintenance

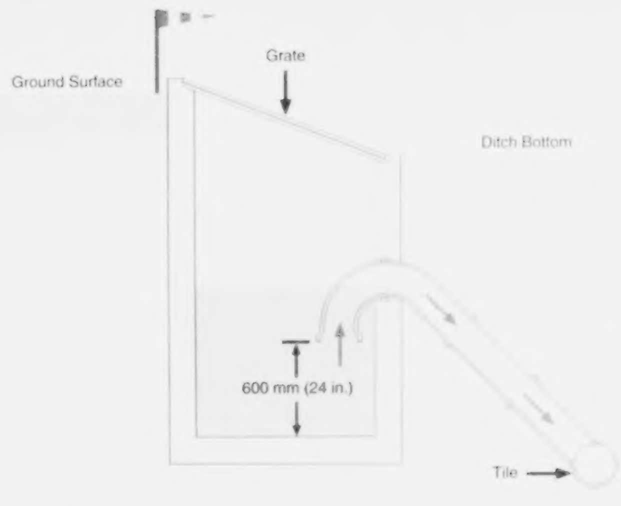
Catch Basins

Catch basins are covered by a grate and located in low-lying areas. They intercept surface water and are connected to a subsurface drain for transmitting water to an outlet (see Figure 20).

- For maintenance purposes, circular catch basins need a minimum diameter of 600 mm (24 in.) and square or rectangular catch basins need a minimum dimension of 600 mm (24 in.).
- Design the grate to prevent plugging by debris and be removable.





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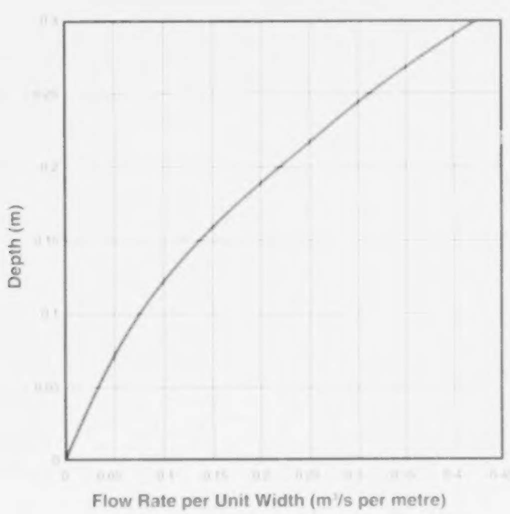

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3 Drainage System Structures

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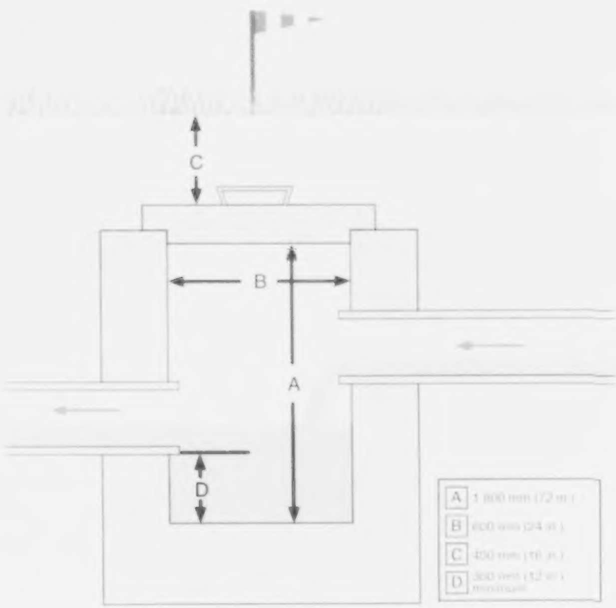

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- For maintenance purposes, circular catch basins need a minimum diameter of 600 mm (24 in.) and square or rectangular catch basins need a minimum dimension of 600 mm (24 in.).
- Design the grate to prevent plugging by debris and be removable.

- Position grate vertically or sloped more than 45 degrees.
- Equip them with a sediment trap no less than 300 mm (12 in.) deep.
- Identify the catch basin location clearly on-site with a marker or record through details on drawings, GPS location coordinates, etc.
- Equip all catch basins with a full flow restrictor plate that's readily available if liquid manure or biosolids are applied upslope of the catch basin.

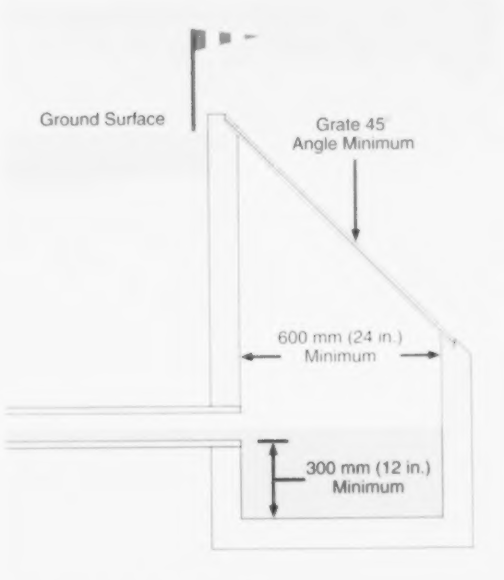


Figure 20. Catch Basin

Blind Inlets

Blind inlets are recommended for depressional areas where shallow surface drains are not practical and/or where surface ponding occurs.

- A 500 mm (20 in.) wide trench 3000 mm (12 ft) long, filled to the top of the trench with 30 mm (1¼ in.) washed stone, serves as an excellent inlet (see Figure 21).
- A geotextile placed horizontally at 300 mm (12 in.) deep will add to the life of the inlet, requiring replacement of only the upper layer of stone (see Section 2.10).
- Identify the location of blind inlets on-site with markers or record through details on drawings, GPS location coordinates, etc.

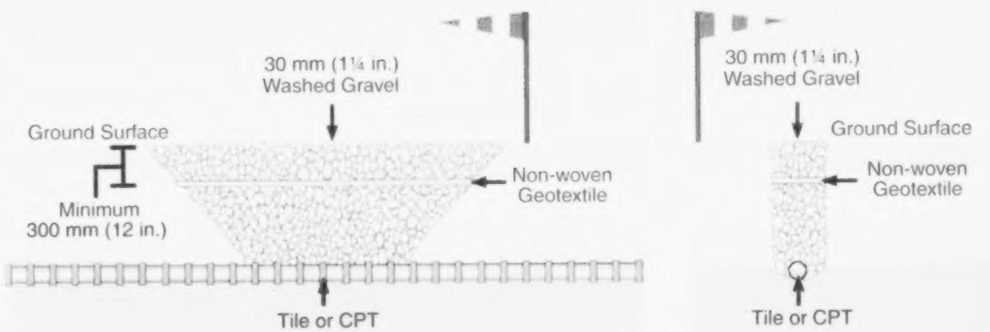
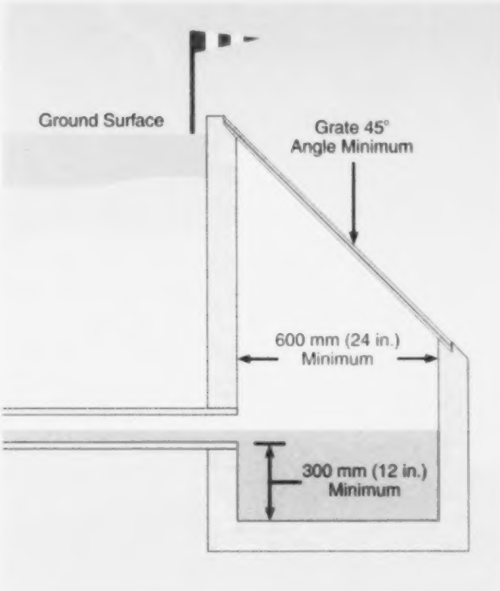


Figure 21. Blind Inlets

- Position grate vertically or sloped more than 45 degrees.
- Equip them with a sediment trap no less than 300 mm (12 in.) deep.
- Identify the catch basin location clearly on-site with a marker or record through details on drawings, GPS location coordinates, etc.
- Equip all catch basins with a full flow restrictor plate that's readily available if liquid manure or biosolids are applied upslope of the catch basin.



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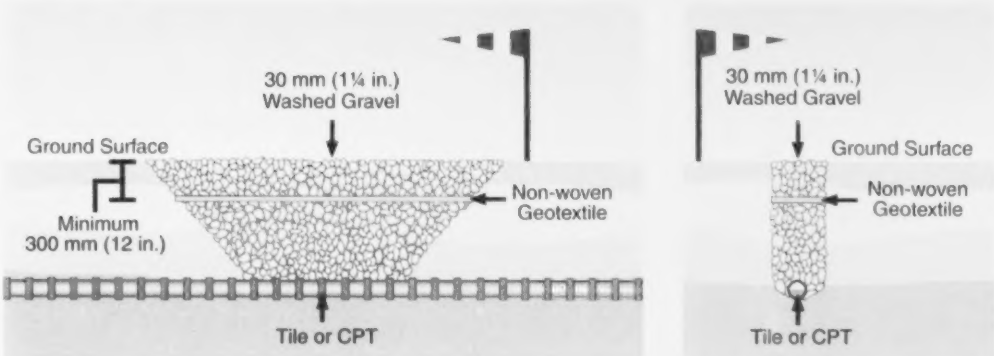


Figure 21. Blind Inlets

3.4 Junction Boxes

Use junction boxes to connect three or more drains, connect two drains at different elevations and serve as a junction where a drain size or drain direction changes abruptly (see Figure 22).

- Base the size of a junction box on accessibility for maintenance:
  - o circular structures – minimum diameter of 750 mm (30 in.)
  - o square or rectangular structures – minimum dimension of 600 mm (24 in.)
- If junction boxes are buried, provide a minimum depth of soil cover of 450 mm (18 in.) where grades permit and construct to adequately support any load placed on the junction box by farming equipment.
- Design junction boxes to facilitate cleaning and other maintenance. Provide a sediment trap with a minimum depth of 300 mm (12 in.), and increase depth for longer intervals between maintenance.
- Clearly identify the junction box location on-site with a marker or record through details on drawing, GPS location coordinates, etc.

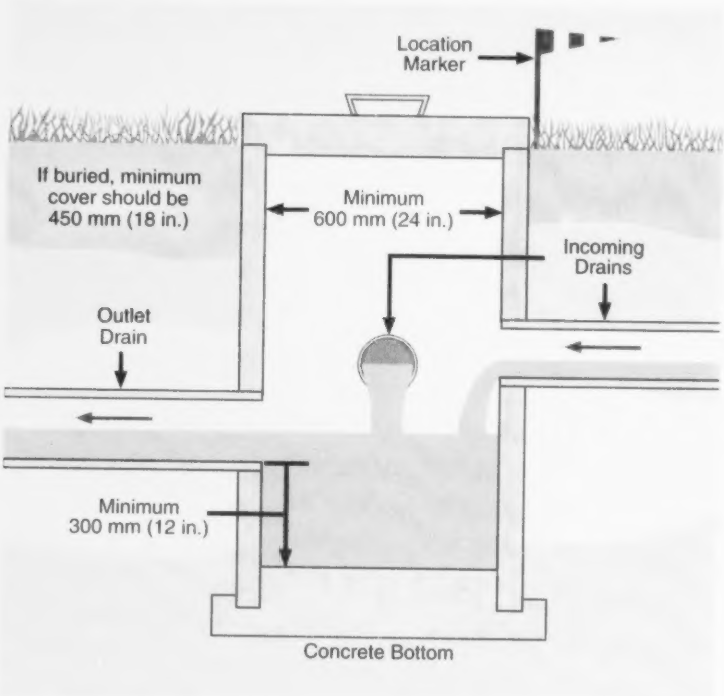
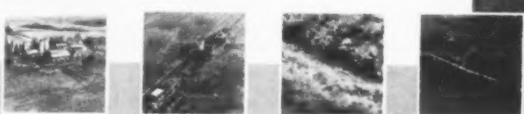


Figure 22. Junction Boxes

3.5 Relief Wells and Breathers

Flow conditions may improve by installing a breather or vent at the upper end of a very steep section of main drain and a relief well at the base of the slope (see Figure 23). These accessories improve the flow in the drain, reduce the hazard of drain failure, and often the need for changing pipe sizes. Where possible locate relief wells and breathers in fence lines (see Section 2.16). Protect relief wells and breathers by a screen or mesh, and locate at ground level in fence rows or where they won't be damaged. Clearly identify the location of relief wells and breathers on-site with a marker or record through details on drawings, GPS location coordinates, etc.



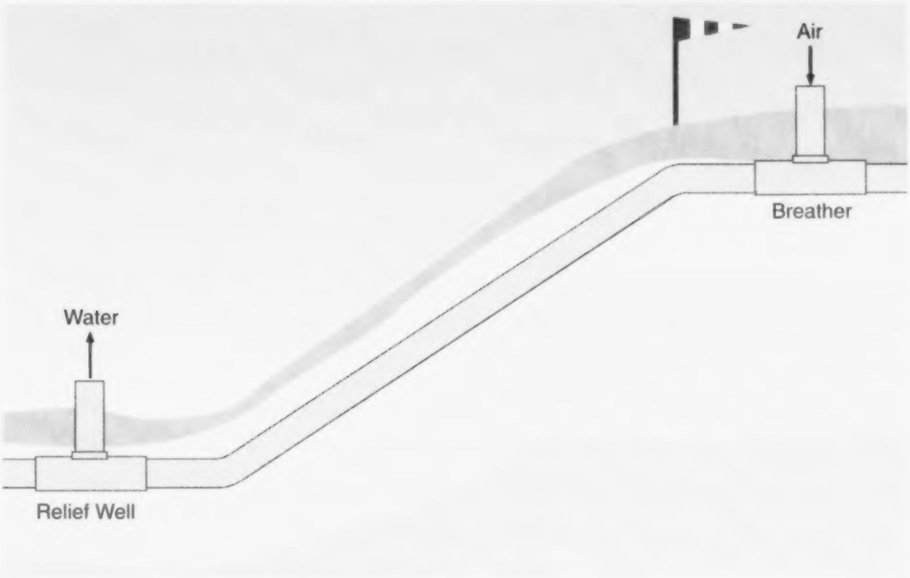


Figure 23. Breathers and Relief Wells

Relief Wells

- Wells relieve the pressure in drain lines that might otherwise cause the lines to blow out and fail.
- Install a relief well near the base of a steep slope where the grade changes abruptly to a flatter slope.
- Use a relief well to relieve internal pressure where there are surface inlets.
- The diameter of the vertical relief well should be equal or greater than the drain line.
- Relief wells are constructed by placing a T connection in the line and fitting a vertical riser into the T.
- Exit the riser to the ground surface, and protect the exposed end by a mesh or screen to prevent the entry of rodents.

Breathers

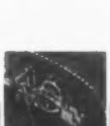
A breather is a T connected to a short riser in a drain, located at the top of a steep slope to improve flow conditions in the pipe. Breathers improve flow in long lateral drains in saturated soil where air is prevented from entering the drain and the drain gradient is usually quite flat.

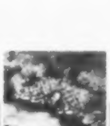
3.6 End Caps and Plugs

Cap the upper end of each subsurface drain line – if not connected to a structure – with a tight fitting plug or cap made of the same material as the pipe or other durable material.

3.7 Siphons

Inverted siphons are used where there is a need to run a drain below obstructions such as a pipeline or road. Common practice is to construct inspection chambers on each side of the obstruction and a connecting pipe below (see Figure 24).



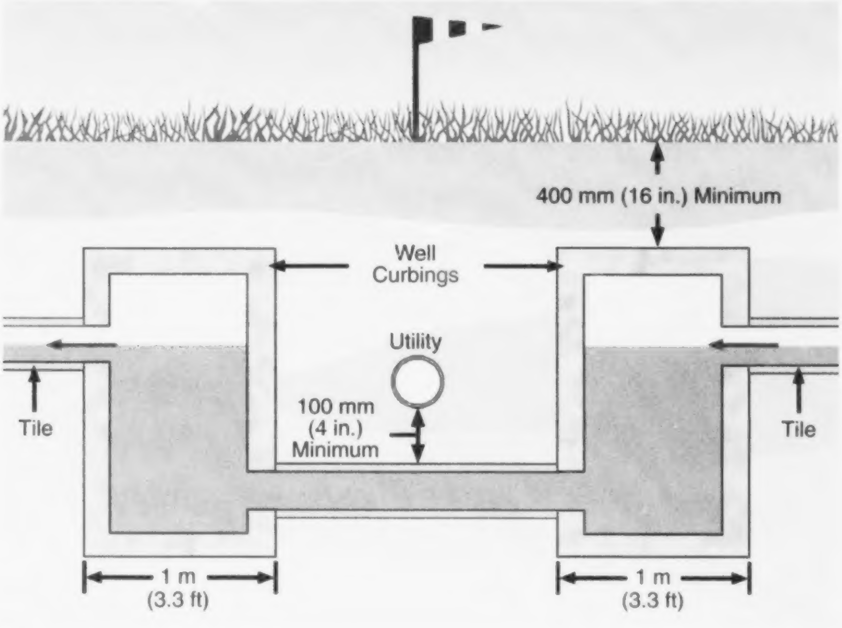


Figure 24. Inverted Siphons
Source: Journal of Hydraulics. ASCE, 1972 No. 1, p. 45.

3.8 Drain Crossings

When a subsurface drain crosses under farm lanes, roads, waterways or ditches, construct it of extra-strength pipe to withstand expected loads and should be watertight (see Figure 25).

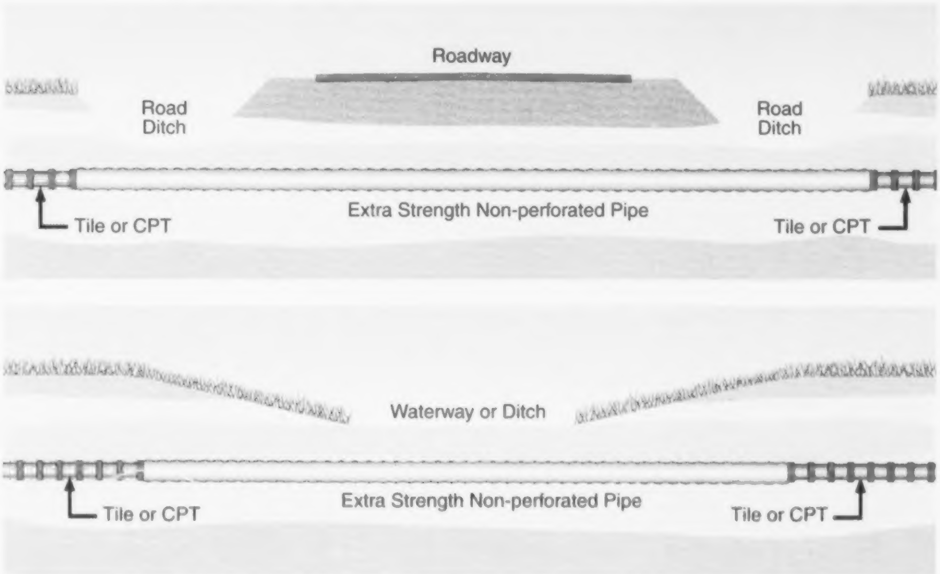


Figure 25. Drain Crossings

3.9 Inline Flow Control Devices

Inline flow control devices are specially designed structures to manage the water flow in a subsurface drain. Often used for water table management, these devices also stop flow in a drain contaminated from a spill e.g. pesticide, gasoline, manure, etc. (see Figure 26). Pick a strategic location for control devices for desired objective and to avoid blowouts and flow restrictions during normal drainage operation mode.

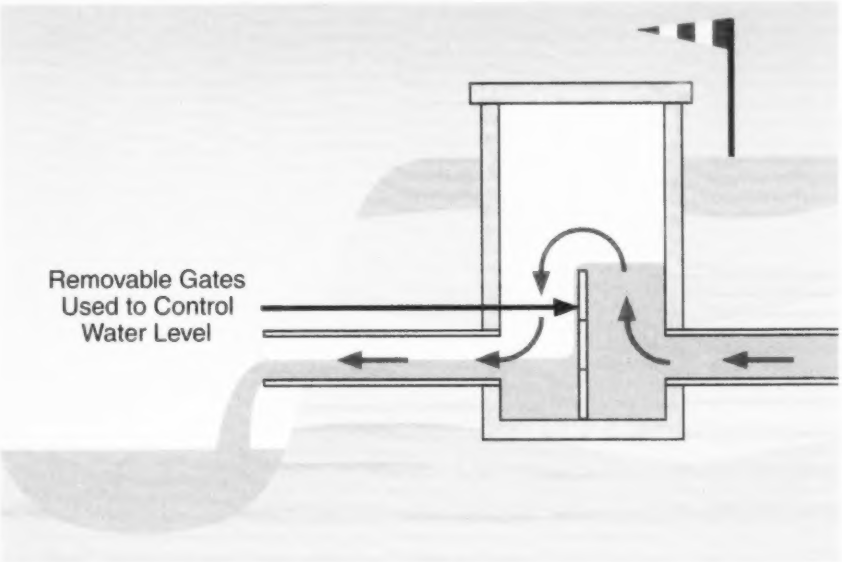


Figure 26. Drain Tile Water Control Device

4. Utilities and Road Crossings

The word utility in Section 4 includes the works of a public utility, defined in the *Drainage Act, 1990*, and the works of a road authority.

4.1 New Utilities Affecting Existing Drainage

Planning

Installing pipelines, cables and other buried utilities on farmland may disrupt existing drainage systems. The utility must ensure that, after construction, the quality of drainage within the right-of-way is equivalent to or better than drainage in the work area and adjoining lands prior to construction.

The location of utilities and roads may affect the design of future drainage systems. Before installing utility works, be sure the utility discusses with owners the plans for new or additional drainage installations across the proposed right-of-way, so suitable arrangements can be made. After construction is complete, inspect the tile drainage systems carefully to ensure proper repair.

Construction of Utilities Affecting Open Ditches

- Install buried utility works at a minimum of 0.75m (2.5 ft) below the bottom of the ditch, and don't interfere with the flow of water in a drainage ditch.
- At the point where a utility work crosses a ditch, protect the ditch banks from slides and erosion.
- Remove all debris and rubbish from the ditch before leaving the site.

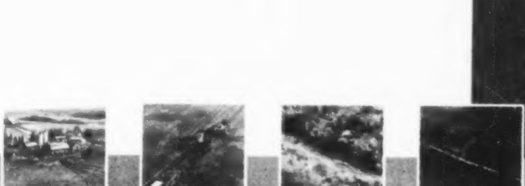
Construction of Utilities Affecting Tile Drainage

The utility is responsible for the repair of all subsurface drains damaged by their construction work, on or off the right-of-way or work area.

Repair damaged, cut or removed drains immediately so the system will function properly, or cover the ends to prevent the soil entry. If the drain pipe is damaged, broken or collapsed, or the grade is altered, remove the pipe to 1 m (3.3 ft) beyond the affected area, and replace with new pipe of the same size and on the design grade.

Where a work area extends over land containing lateral subsurface drains, the utility work on the surface must not adversely affect the subsurface drains through breakage or collapse of pipe. This can be checked by:

- visual inspection up the pipe using a strong light where the distance does not exceed 10 m (33 ft), or
- inserting a 75 mm (3 in.) diameter probe through the pipe for the width of the work area to ensure there is no drain failure or blockage through tubing collapse or tile breakage



Where a utility work crosses under a drain line, ensure a minimum clearance of 50 mm (2 in.) between the invert of the drain line and the top of the utility work. If it crosses over a drain line, a minimum clearance of 50 mm (2 in.) is required between the top of the drain pipe and the bottom of the utility work.

Where a utility work crosses under a drainage system, tamp the fill below the drains and compact to the same density as the surrounding soil. Use well-pulverized soil, free from stone, debris or frozen lumps. Shape and plane the trench bottom to the original grade, and place a satisfactory support under the drain. Blind the drain pipe with 100 mm (4 in.) of stone-free soil and backfill the trench, leaving a minimum crown of 200 mm (8 in.).

Drain crossings are the portion of disturbed subsurface drain across the utility work excavation.

If crossings are wider than 3 m (10 ft)

- use metal pipe or other high-strength, continuous, rigid pipe (clamp joints with regular manufactured connecting bands) or a pipe of larger diameter than the drain pipe
- install and tamp the backfill so it won't be crowded out of line by vibration or frost
- seal the joint at each end with concrete

If crossings are less than 3 m (10 ft)

- lay drain pipe on a satisfactory support
- use additional support in unstable soils

Where the utility work excavation has cut a series of lateral drain lines, construct a new main drain parallel to the upstream side of the utility work, or right-of-way easement with a minimum number of crossings of the utility. Construct a silt basin at the downstream side of the right-of-way for each drain crossing. Be sure the upper end of severed drains are closed tightly with an end plug.

Carefully inspect all drain lines prior to backfilling to ensure pipes are on grade, correctly aligned and properly installed. The allowable variation from grade must be not more than specified in Section 7.6. The ground surface should be graded to eliminate depressions where water might collect.

4.2 New Drainage Affecting Existing Utilities

Third-party contractors are the greatest threat to buried utilities. Pipelines companies are required to establish monitoring programs to verify pipeline integrity that follow the requirements established in the Canadian Standards Association Standard Z662 *Oil and Gas Pipeline Systems*.

Planning Your Drainage Tile Installation Work

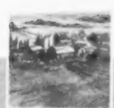
- Contact the utility company in advance of the tile drainage work and advise them of the site plans for installing new or modified tiles.
- Arrange for locates to verify the horizontal and vertical position of the buried utilities. Stakeout and crossing inspections are provided free of charge by utility companies when arranged in advance of work commencement.

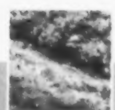
- Discuss the additional work and cost implications of crossing the buried utility with the company before work starts. Utility companies understand the implications of altering conventional drainage systems. Ensure there's a mutual understanding about cost-sharing arrangements for the work. This can only be determined by submitting plans and estimates before starting work.
- Avoid the installation of tile runs within the utility easement in the design of tile systems. Future utility maintenance activities can damage tile facilities. Header pipes can be positioned along the right-of-way boundaries to collect drainage from individual runs.
- Design the tile drainage system to minimize the number of tile runs crossing the buried utility. Use a larger header pipe to facilitate a single crossing of the buried utility.
- Maintain the following minimum clearance from the buried utility for drainage system crossings:
  - 50 mm (2 in.) for plastic tiles
  - 300 mm (12 in.) for culverts
  - 750 mm (30 in.) for ditches

Installing Tile on the Right-of-Way

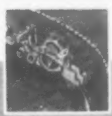
Drainage system designs must be submitted to the utility for approval. The utility company usually responds to a crossing request within 10 working days. Start by obtaining written permission from the utility company. Their objective is to allow drainage work to be completed while ensuring the utility is protected from damage by construction equipment. Utility companies also want to avoid impacts or damage to the drainage system that may be caused by future utility maintenance along the easement.

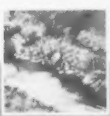
- After approval is received, contact the utility at least three working days in advance of starting work near the easement. Notify Ontario One Call (1-800-400-2255, *www.on1call.com*) or the utility company directly.
- Ensure an inspector is present when work takes place on the utility easement. A crossing stakeout is performed when the work begins, and the property owner and contractor will sign the form.
- Hand dig to expose the buried utility before beginning mechanical excavation. Keep mechanical excavation more than 600 mm (24 in.) away from an exposed utility.
- Where drains won't go over or under a work without a deviation from grade, lower the work if the utility can be disrupted, or construct an inverted siphon (see Figure 24).











5. Drain Design Considerations and Problem Solutions

5.1 General

Certain property features can create problems with a tile drainage system and must be considered during the design of the system. This section identifies some of these features and provides recommendations to minimize future problems. If these features result in problems to the tile drainage system, this section also provides recommendations to improve the problem.

5.2 Tree Roots

If tile drains carry water for prolonged periods during the growing season, they can be plugged by tree roots.

Design Considerations

- Route the tile at least 30 m (100 ft) away from water-loving trees such as willow, soft maple, elm and poplar, and at least 15 m (50 ft) away from all other trees.
- If rerouting isn't possible, remove water-loving trees for a distance of 30 m (100 ft) from a drain which carries water during the growing season for a prolonged period. Other trees need a clearance of 15 m (50 ft) from a drain. Refer to OMAFRA article, *Farm Tile Drains and Tree Roots, www.ontario.ca/omafra*
- If a tree can't be removed, or the drain rerouted, use continuous non-perforated pipe for a distance of 15 m (50 ft) on either side of the tree.
- Fruit trees are not included in these recommendations. Locate a header drain at the higher end of an orchard to intercept prolonged summer flow in lateral drains.

If You Encounter the Problem

If a tile drain becomes blocked with tree roots:

- remove and replace the section of blocked tile
- remove the tree causing the problem, or
- replace the tile using continuous non-perforated pipe for a distance of 15 m (50 ft) on either side of the tree

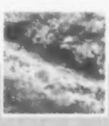
5.3 Quicksand

Quicksand is a condition – not a soil type – that usually occurs in small areas within a field and never the entire field. The upward pressure of groundwater on fine sand or silt prevents soil from settling firmly together. The soil's loss of bearing capacity may adversely affect the grade of the drain and the life of the system because the soil can't support an unconfined load.

Design Considerations

- Install drains when subsoil conditions are dry, if possible, or
- Permit all areas with quicksand to drain through an open channel or a sacrificial tile before laying the permanent drainpipe, or
- Install tile on a solid bedding to provide a stable support.






If You Encounter the Problem

Replace drainpipe if quicksand adversely affects the grade on a section of tile enough to disrupt the gravity flow of water.

5.4 Unstable Soils (need for drain protection)

Many fine sand and silt soils are unstable at drain depth because particles are non-cohesive, move easily when saturated and may enter the drainage pipe. Water from the surrounding soil enters from below the pipe, and soil particles (fine sands and silt) carried by the water are deposited in the pipe. This occurs shortly after the tile drainage system is installed because the soil surrounding the pipe is loose and any pre-existing soil structure is destroyed. Soil material found in the drain pipe is often coarser than parent material because finer soils particles have washed away. Initial installation is a very critical period. Self-cleaning drain grades are usually not feasible in unstable soils. Drains won't flush out naturally when the depth of sediment in the pipe exceeds 20 mm (¾ in.).

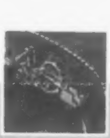
Design Considerations

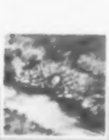
Check the county soil map to determine the subsoil characteristics of the area. Just prior to installation, dig test holes to below drain depth and note if the soil and water is unstable. If still concerned after completing these steps, test if subsoil material is likely to enter a drain and determine if envelope filter protection is needed. The following simple test is an indication of need. It's positive when failure occurs. Be sure to conduct further tests if failure doesn't occur during the test.

1. Cut the top and bottom from two metal coffee cans and solder the two cans together to create an open cylinder 280 mm (11 in.) long and about 100 mm (4 in.) in diameter.
2. Cut the centre out of the plastic lid to leave a 12 mm (½ in.) retaining ring.
3. Fit a circular stiff screen having openings of 2-3 mm (⅛ in.) in the retaining ring on the bottom of the can. Place the can on a flat surface.
4. Take a sample of moist soil from drain depth and gently place it on the screen inside the can.
5. Tamp, using a 25 mm (1 in.) tamper, the soil to the density of the parent material to a depth of 25 mm (1 in.).
6. Raise the can about 6 mm (¼ in.) off the flat surface.
7. Slowly pour water into the top of the can but don't erode or wash the soil. Add water to a depth of 185 mm (7 in.).
8. If the water doesn't wash out the bottom after being left undisturbed for 15 minutes, the drain probably does not require a filter envelope.
9. Test suspect soils in a commercial soil laboratory.

If drain filter protection is required

The types of filter material now available in Ontario provide protection for most problem soils provided the soils don't contain a large proportion of fines. Filter failure can also occur through sealing by fine silt and clay particles, and by iron and manganese oxides and sulphates. Filters also fail by mechanical tearing and abrasion. Roll and unwrapped filter materials rely on good field installation for good performance.



Drain protection material on the market:

- Filter cloth material (sock) such as a polypropylene or polyester knitted woven material is applied to plastic drainage tubing at the plant.
- Pipe wrap material used for larger pipe may be geotextile or filter cloth. Ensure the entire pipe is securely wrapped.
- Graded gravel envelopes are another option, but are expensive.

Filter consideration

- Weather and storage deterioration affect filter material. Protect filter wrapped drainage pipe from ultra-violet radiation of the sun and install as soon as possible. Heat generated within maxi-coils adversely affects the life of the filter. Storage in wet conditions may promote fungus growth on filter material.
- Some cost savings are possible in soils where drains require filter protection, by installing non-perforated corrugated plastic mains. Install a 100 mm (4 in.) drain, protected with an envelope filter, parallel to the main drain if some drainage is required.
- It's not practical to design a manufactured filter for a narrow range of grain sizes. A conservative stability criteria giving protection in the critical particle size range is that the 50% size of the grain size distribution curve is not greater than the average diameter of filter opening. If the average opening of filter cloth is 0.15 mm ([illegible] in.), then the $d_{50}/0.15 = 1.0$, and the d_{50} is 0.15 mm ([illegible] in.).

If filter protection isn't required, but sediment migration into the tile may occur

- Design and install the tile with as much grade as is available.
- Don't install tile, or remove installed tile because it can't be left unconnected.
- Be sure construction in these problem soils takes place during dry periods.

If You Encounter the Problem

- When a tile is blocked with sediment, investigate the system to locate the source of the sediment and correct the problem. Replace or abandon the section of blocked tile.

5.5 Iron Ochre

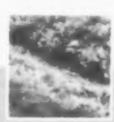
Ochre, an iron oxide, affects about 2% of drainage systems in Ontario. It occurs in two classes of soil – very open soil such as acid sand, and soil in bottom land with perennial groundwater that produces anaerobic conditions making iron ochre soluble in drainage water. Subsurface drainage systems in soils with available soluble iron (Fe+3) and organic matter are adversely affected by bacteria-forming iron ochre in pipe drain openings and inside the pipe.

Ochre accumulates through chemical or microbiological process, or both. It's a natural condition usually found where new land – sandy in nature with high organic matter – is cleared and drained. Recognized by brilliant red accretion at drain outfalls, iron ochre can seal drain openings very quickly.

Design Considerations

- There's no solution as iron ochre is caused by changes in chemical condition within the soil profile, and it's difficult to clearly identify areas where this problem may occur in advance.






If You Encounter the Problem

- Replace or abandon the original system when it fails.

5.6 Blowouts and Cave-ins

Blowouts in a field are recognized by a hole at the surface above a drain. Blowouts can occur due to:

- blockage of the pipe (roots, collapsed pipe, etc.)
- excess hydraulic pressure in the tile due to steep upslope grade
- excess hydraulic pressure in the tile due to inadequate tile size

Design Considerations

- Ensure tile is properly sized to handle flows.
- Incorporate a relief well into the design, or use larger tile, if it's suspected that a particular tile installation will result in excess hydraulic pressure due to steep upslope grade.

If You Encounter the Problem

- Inspect the field surface regularly for blowouts and cave-ins, and repair the drain pipe for any problems found.
- Consider installing a relief well to relieve excess hydraulic pressure if the blowout was a result of a steep upslope grade.
- Consider installing additional tile for added flow capacity if the blowout was a result of inadequate tile size.

5.7 Manure, Biosolids and Waste Water

Organic growths in field drains can obstruct the flow of tile drains. These include manure, biosolids, septage, milkhouse washwater, etc. reaching the drainage system through soil macropores or direct drain connections.

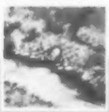
Design Considerations

- Locate drainage pipe away from manure storages or barnyards. Refer to regulations under the *Nutrient Management Act, 2002*, for the distance tile must be located from various structures.
- If existing tiles appear to contain nutrient contaminants or organic growth, don't connect these tiles to a new drainage system.

If You Encounter the Problem

- Replace tile drains obstructed with organic growth, as needed.
- Apply nutrients needed for crop production at rates recommended by best management practices.
- Apply manure at volumes and methods recommended by best management practices and in accordance with the requirements of the *Nutrient Management Act, 2002*.
- Discharges from septic tanks, grey water discharges, milkhouse washwater, silo effluent, etc. must not connect directly to the field tile system.



5.8 Plant Roots

Roots of commercial crops don't usually penetrate into field tile drains. However, when drains carry water during dry periods, crops such as alfalfa, brome grass, rye grass, canola, sugar beets and sometimes corn may create problems when their roots enter the drain. While these roots can cause blockages in the tile, they usually wash out of the drain when the plant dies. Horsetail (*Equisetum*) has a very deep root system and frequently will plug drains.

Design Considerations

- There are none, but ensure landowner is aware of the potential problem.

If You Encounter the Problem

- Avoid growing any problem-causing crops.
- Flush the roots from the tile using low pressure jet cleaning.
- If the blockage persists, remove or replace the blocked section of tile, and consider replacing the problem area with a larger diameter drain pipe.

5.9 Soil Management

An important component of an effective tile drainage system is the ability of gravitational water to flow through the soil to the drain tile. Two types of soil conditions may cause drainage problems – soil management problems and slow drainage in new installations.

Poor soil management restricts water movement through the soil to the tile drain. Examples of these soil management problems include:

- soil compaction of the surface layer
- soil compaction at the plow layer for sandy loam soils
- complete inversion of the plow furrow which seals the layer below

Field drainage systems don't always provide a complete answer to a drainage problem. It's important to encourage water movement in the soil, even after drainage. Tile drains don't pull water – they receive water that gravitates to them. Water movement through compacted and puddled soil layers is very difficult.

Newly installed tile drainage systems often take a few years to reach peak performance. This occurs most commonly with systems installed in land parcels that haven't been tile drained before and where the water level in the soil is close to the surface most of year. The high natural water table limits earthworm and root penetration into deeper levels, and encourages the soil to settle tightly together. Both factors limit the immediate effectiveness of tile drainage system.

Design Considerations

- There are none. It's the landowner's responsibility to ensure soil will respond to tile drainage, and the contractor's responsibility to install the tile professionally.




If You Encounter the Problem

For soil management problems:

- Improve compaction of the surface soil layer with tillage and cultural practices.
- Reduce the effects of deeper soil compaction through deep tillage or plant deep-rooted crops such as alfalfa and red clover.
- Refer to OMAFRA *Best Management Practices for Soil Management*, BMP No. 6.

For slow drainage in new tile installations:

- Use best management practices to improve soil tilth.
- Take no immediate action – soil drainage will improve over time as earthworms create large pores and cracks form, creating flow paths to the drain tile. It may take from 5-10 years to reach optimum drainage.
- Plant deep-rooted crops such as alfalfa or red clover. The roots create pathways in the soil for the water flow.
- Improve pathways for water to move to the tile with subsoiling. It's effect may be short term, and be careful to do it correctly and under proper conditions so the problem doesn't worsen.

5.10 Organic Soils

Thin layers of organic soil over sand or over heavy clay soil don't usually drain.

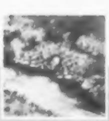
Design Considerations

- Avoid installing tile in these conditions.

If You Encounter the Problem

- The land is best used for grass or pasture.
- Deep plowing to mix the soils won't alleviate the problem.



6. Materials and Standards

6.1 General

Use material in subsurface drainage systems that meet the requirements of the relevant Standard. Advise contractors of any deleterious chemicals that may be in soil where the drainage system is installed. Don't install concrete pipe in soils containing sulphate unless the pipe is manufactured using sulphate resistant concrete. Examine soils containing traces of iron to ensure the proposed drainage system is effective in these soils (see Section 5.5). Refer to OMAFRA Factsheet, *Drain Problems*, Order No.84-017.

Use straight clay and concrete drain tile that's approximately circular in cross-section. Be sure ends are square and the inside surface smooth. Avoid pipe with cracks, broken pieces and checks that decrease strength or let soil into the drain. Use sewer pipe or corrugated steel pipe where drain pipe may be crushed from loads applied at the surface by machinery or other traffic, or if frost is a problem.

6.2 Clay Drain Tile

Manufacturers in Ontario adopt the following recommendation for voluntary use: that standard clay drain tile meets all American Society for Testing and Materials specifications as set out in designation C4 (clay drain tile) and Designation C498 (perforated clay drain tile).

6.3 Concrete Drain Tile

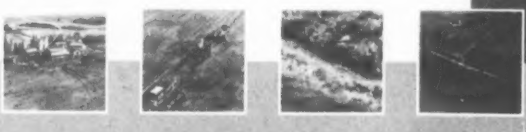
Manufacturers in Ontario adopt the following recommendation for voluntary use: that concrete drain tile meets the specifications as set out in American Society for Testing Materials Designation C412 (drain tile).

6.4 Corrugated Plastic Drainage Tubing

Plastic tubing manufacturers voluntarily adopt the *Land Improvement Contractors of Ontario – Standard Specification for Corrugated Plastic Drainage Tubing, 2006* for use in Ontario.

6.5 Fittings

- Use fittings to facilitate the construction of a subsurface drainage system and improve its effectiveness, maintenance and efficiency.
- Fittings include: Ts, cross-Ts, Ys, end plugs, end caps, bends, elbows, reducers, clay tile to plastic tubing adapters, adapters for changes in diameter and coupling for lengths of plastic tubing.
- Use strong fittings that are compatible between manufacturers used.
- Use corrugated plastic tubing couplers that meet tensile forces specified in the *Land Improvement Contractors of Ontario – Standard Specification for Corrugated Plastic Drainage Tubing, 2006.*



6.6 Envelope and Filter Materials

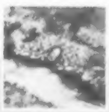
Many soils are unstable at drain depth from upward water pressure, fine non-cohesive soils and fine organic materials. An envelope sock produces a hydraulic benefit, and the envelope material restrains the entry of base soil material which surrounds the drain. Experience has shown that soils, such as fine sandy loams and some silts, with a single grain structure in the range of 50-250 microns are susceptible to erosion into drains.

- Completely surround the drain pipe with the envelope to prevent particle movement into the drain.
- Use envelope material suitable for underground use with a long life expectancy (see Section 7.3).
- Thin synthetic filter materials deteriorate in sunlight. Check the date on the production tag to ensure it wasn't stored too long.
- Use material with permeability as large as the design criteria will permit while still retaining soil material.
- Repair or replace any envelope material damaged in transit, storage or during construction.
- Install drains in sand and silt soils only under dry conditions, or when the water table is at the lowest elevation. Envelope materials can plug immediately when installed in sand and silt soils with a high water table (see Section 7.4).

6.7 Geotextiles

Geotextile materials are synthetic products used in land drainage to improve the drainage, or improve stability of a structure or the soil. The most important use for geotextiles is a base material between the soil and armour to prevent bank erosion and prevent mechanical failure at outfalls. Geotextiles are also used for vertical drainage as a substitute for gravel.



7. Construction

7.1 General

This section of the guide defines the minimum standard of work the Ontario Ministry of Agriculture, Food and Rural Affairs considers satisfactory for the construction of subsurface drainage systems used to drain agricultural land.

Install all agricultural tile drainage systems in accordance with the *Agricultural Tile Drainage Installation Act, 1990*. The Act requires the licensing of tile drainage contracting businesses, their equipment and equipment operators. Landowners installing tile on their own property with their own equipment are exempt from this legislation.

This section is not a complete specification since conditions vary across Ontario. Work conditions may dictate the use of other construction practices, equal to or higher than this guide, to meet specific performance criteria. Landowners may impose more rigid requirements but lesser requirements are not accepted.

Ensure workmanship, materials and methods of construction conform to industry standards and practices. If a pit excavation is required to observe the standard of workmanship or materials, the contractor must make labour available for this work.

Review other sections in the guide that apply to the construction section before work is done.

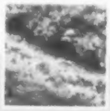
7.2 Safety

- Contractors must comply with existing federal, provincial and municipal laws, with particular attention to the *Occupational Health and Safety Act, 1990*, and regulations.
- Protect people working in a trench from cave-ins, ensure excavations are safe and adequately supported, and don't allow anyone to work alone in a trench. Refer to Regulation 213/91 of the *Occupational Health and Safety Act, 1990*.
- Erect safety barricades and warning signs where there is public access to drain construction.
- Adopt systems of work and use equipment that is safe and won't risk people at work or others affected by the activities of workers, within reason.
- Call before digging. Identify and mark the location and depth of underground utilities before construction.
- Avoid hazards by protecting moving parts of the drainage machine with proper guards.
- Don't permit casual observers close to construction operations.
- Keep livestock away from the field where construction is in progress or where trenches are open.

7.3 Inspection and Handling of Material

Contractors must inspect drain materials before and during installation. All material must be satisfactory for the intended use and meet the material requirements in Section 6. Protect material from hazards and exercise care during handling to avoid damage to the material.






Inspection Before Installation

- Examine material for damage after delivery to the site. Return damaged or unsatisfactory material to the supplier.
- Keep clay and concrete pipe away from flooding. Stockpile it on suitable material to eliminate direct ground contact during periods of freezing and thawing.
- Protect coils of plastic pipe from damage and deformation.

During Installation

- Ensure contractors do final inspection of all pipes. Reject any defective or damaged clay, concrete or other rigid drain pipe. Cut out defective or damaged sections of plastic pipe and join the tubing in accordance with Section 7.13.
- Install perforated plastic tubing when plastic tubing is used, unless otherwise specified on the plan.

7.4 Working Conditions

Install drains during favourable working conditions – usually between May and October – and ideally during June, July and August.

- Avoid installing a drainage system in saturated land surface conditions and very wet soil profiles as it greatly diminishes the drainage system response.
- If the drainage system can't be installed during dry soil conditions, the system may not perform effectively until the internal drainage of the soil is re-established.
- If soil conditions are extremely saturated, delay installation until conditions are favourable.
- Be careful when using a drainage plow in wet conditions on fine-textured soil. If the soil surface doesn't heave substantially, soil structure and drainability will be impaired.

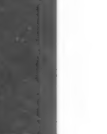
7.5 Control of Direction

Fix horizontal direction or alignment to ensure lateral drains are straight and parallel as topography allows and where uniform depth can be maintained. The tolerance for horizontal alignment of lateral drain lines intended to be parallel is 3% of drain spacing.

Change horizontal direction to maintain the specified grade, not impede the flow of water because of excessive roughness and allow tile joints to be fitted according to soil conditions.

Horizontal direction may be changed by one of the following methods:

- Construct the drain on a gradual curve so the drainage machine can install the pipe in the trench while maintaining grade.
- For concrete or clay tile systems, construct a gradual curve by shaving the inner side of the curve and chipping the drain tile. The radius of curvature is not less than 1.5 m (5 ft).
- For plastic tubing, make directional changes without fittings, provided the centre-line radius of the bend is not less than five times the tubing diameter.
- Use manufactured bends or fittings so the change in directions is a smooth curve.
- Use junction boxes and silt basins.



7.6 Control of Grade

- Install all drains to a predetermined grade and line, and constantly maintain grade control during installation.
- Construct the grade so the drain provides the capacity required for the drained area.
- A variation in grade is tolerated where the actual drain capacity exceeds the required capacity.
- No reverse grade is allowed (see Figure 27A).
- Grade tolerances are specified by the regulations under the *Agricultural Tile Drainage Installation Act, 1990*. Do not deviate the constructed grade from planned grade by more than 15% of the internal diameter for drain sizes of 200 mm (8 in.) or less, or 10% of the internal diameter for diameters greater than 200 mm (8 in.) (see Figure 27B). These deviations are allowable, provided they're gradual over a distance of not less than 10 m (33 ft) (see Figure 27C) and don't occur consecutively both above and below grade in any 30 m (100 ft) length of drain (see Figure 27D).

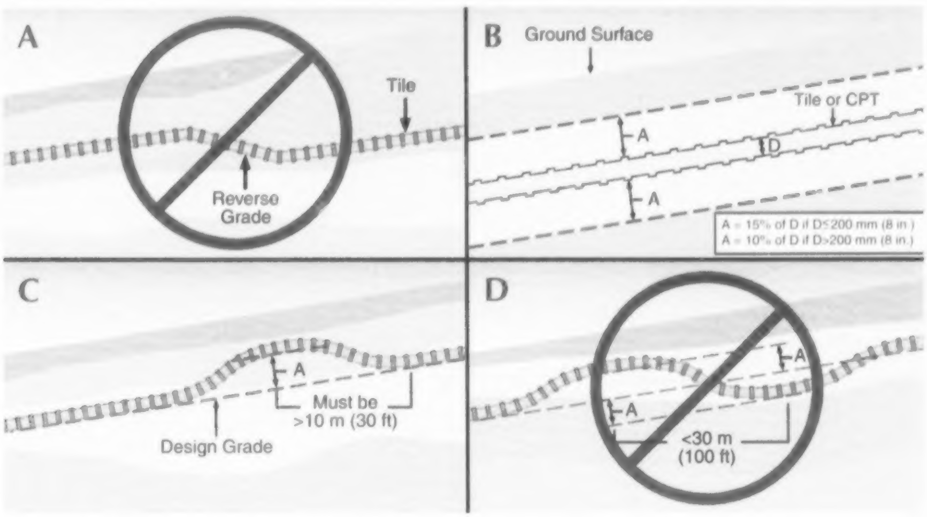
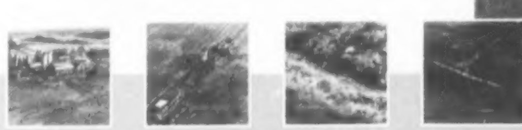


Figure 27. Allowable Variation in Grade

7.7 Laying Pipe – General

- Use an installation method that's compatible with the drainage system design and the existing soil conditions.
- Install drains to the design depth, true to line and gradient, and the trench bottom formed to secure the pipe in a straight line.
- Ensure the bed is firm and free of loose soil.
- Support drain pipes with a formed bottom – e.g. curved, v-shaped or trapezoidal.
- Avoid laying pipes on soil backfill or in slurry, and secure them to avoid displacement before backfilling the trench.
- Keep the inside of the drain pipe clean during construction, and remove all soil and debris before laying additional pipe.
- Avoid stretching or compressing plastic tubing by more than 7% of its normal length.



- Corrugated plastic drain tubing is affected by temperature.
  - o At colder temperatures, plastic tubing becomes stiff and less flexible – be careful when uncoiling rolls and installing tubing.
  - o At very warm temperatures, plastic tubing deflects, stretches and compresses more easily – be careful when handling under these conditions.

Clay or Concrete Tiles

- In all soils, make the opening between clay or concrete tile wide enough to permit entry of the design flow but small enough to prevent entry of soil.
  - o Make the maximum joint spacing 3 mm (⅛ in.), except where special conditions indicate a wider spacing.
  - o Cover joints with protective material where joint spaces between adjacent drain tiles exceed those such as on the outer side of a curved drain.
  - o Lay perforated tile with the greatest number of perforations closest to the bottom of the drain – or make the drain deeper.
- When shale rock is at grade level, excavate the trench approximately 75 mm (3 in.) below grade level and fill to the planned grade.
- When the trench is excavated below design grade, fill to grade with small gravel or well pulverized soil and tamp to provide a firm foundation for the pipe.
- Install drain tubing so surface and earth loads don't deflect tubing more than 20% of its normal diameter.
- Provide a suitable plug at the upstream end of each pipe to prevent entry of soil into the drain.

7.8 Laying Pipe – Open Trench Installation

Cut drain trenches to the design depth, true to line and gradient, and shape or groove the trench bottom to bed, fit and secure the drain pipe. Ensure trench width allows sufficient space to join tubing and do other minor work in the trench. Start trench construction at the outlet and proceed up slope.

Be sure the width of the trench (measured at the top of the pipe) gives enough clearance between the trench wall and where the pipe is laid, for blinding material to fill the space under the haunch of the pipe and provide lateral support for the drain pipe.

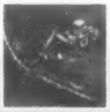
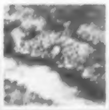
- Maintain a minimum clearance on each side of the pipe of 75 mm (3 in.).
- Take special precautions to protect plastic tubing from failure by deflection when laid in shallow, deep or wide trenches (see Section 2.15).
- Protect plastic tubing from deformation and floating in wet soil conditions.

7.9 Blinding and Backfilling the Trench

Inspecting the installed drain tile may be required prior to blinding and/or backfilling.

- Ensure required drain pipe protection, such as filter, envelope, or stone material, is in its proper place before blinding.
- Connect existing drains, as required, into the new drain pipe before blinding.
- Re-align any tile that is misaligned from trench wall cave-ins before blinding.
- Rectify any deviation of the drain pipe grade, from foreign materials, before blinding.



Blinding

Blinding ensures the pipe and any envelope material remains in place and provides adequate cover to protect the drain pipe from the backfilling operation.

- Blind drain pipe by placing selected material, not more than 40 mm (1½ in.) in size, preferably top soil around the pipe.
- Blind all tiles before backfilling, especially where there is bulk dumping of backfill into the trench.
- Blind the drain pipe immediately after installation by hand shovel or mechanical means. Ensure the pipe and envelope material remains in place.
- Where clay tile is subject to frost, make the depth of blinding 300 mm (12 in.).
- All pipe sizes benefit from compacting the bedding and blinding material along the side walls of the pipe, where allowed.
- Use loam or clay soil (if available) for blinding material on steep grades or where the topsoil contains fine sand.

Backfilling

Carefully backfill trenches with excavated material placed so that pipe is not damaged or displaced.

- Backfill all open trenches at the end of each day.
- Cover the exposed end of the drain at the end of each day to prevent the entry of debris or sediment in wet conditions.
- Ensure fill is firm and not compacted enough to prevent the passage of water to the pipe.
- Fill all trenches to a level sufficiently above the surface of the ground to allow for settlement.
- Do not run a wheel up and down the trench to compress the backfill as this could damage the installed pipe.
- Have traffic cross the trench on the same path each time, and avoid random crossing in several locations.

7.10 Laying Pipe – Plow Installation

- Construct an opening in the soil using drainage plow equipment with a smooth trench bottom, and maintain the opening until the drain pipe is properly installed.
- To provide structural strength, shape the trench bottom to closely conform to the outside diameter, or groove to bed, fit and secure the drain pipe.
- Protect plastic tubing from deformation and floating in wet soil conditions.
- Do not run a wheel up and down the plow trench buildup as this could damage the installed pipe.
- Have traffic cross the plow trench on the same path each time, and avoid random crossing in several locations

7.11 Construction in Non-cohesive Soils

- Non-cohesive soils – including fine sand and possibly some silt – require special construction features depending on soil type and conditions.
- An unstable open trench wall or fluid soil conditions in saturated silt or sand can cause the trench sidewalls to cave and prevent the drain pipe from maintaining alignment. Pipes must be protected until they have been properly laid and blinded.




- Where the trench bottom is unstable such as in fine sandy soil, prevent sediment from entering the drain and provide a firm foundation for the pipe by wrapping the joints or providing a filter envelope.
- Protect tubing from floating off grade when installing plastic tubing in saturated soil conditions.

7.12 Existing Drains

- If existing field drains carrying sewage or farmstead waste are encountered during construction, don't connect them to the drainage system.
- If existing field drains encountered during construction are free from sediment, connect directly to the new system, or connect indirectly with permeable fill carried up or down to the level of the old drains.
- If existing field drains encountered during construction have sediment deposits but will carry water, connected indirectly to the new drain with permeable fill carried up or down to the level of the old drains.

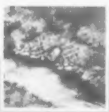
7.13 Connections

- Use manufactured T, Y, couplers, adapters or elbow fittings for connections at the junction of two drains.
  - o Make plastic tubing connections to clay or concrete drain tile using plastic adapters manufactured for this purpose.
  - o Make plastic tubing connections with plastic tubing using manufactured plastic fittings designed for the type of connection made.
  - o Remove a proper length of plastic tubing to allow for a secure connection fit.
  - o Use a junction box or catchbasin to connect multiple drains together. Securely fasten and seal all connections (see Section 3.9).
- Ensure all fittings are compatible with the pipe used.
- Use a plastic coupling when joining lengths of plastic tubing to secure the ends of the tubing in proper alignment and prevent the joint from separating during installation.
- When making connections by cutting a hole in the main drain, be sure the connected pipe doesn't protrude into the drain and obstruct water flow.
  - o Make each connection with manufactured connectors to ensure that capacity or structural strength of the main drain is not compromised.
  - o Make each connection at or above the centre of the drain.
  - o Make the cut hole consistent in size and shape to allow a good fit for the manufactured connector.

7.14 Connections to Municipal Drains

- Obtain approval from local municipalities responsible for the drain for each connection to a municipal drain (*Drainage Act, 1990*, Section 66).
- Do not directly connect lateral drains to a municipal drain, except through a sub main.
- Avoid obstructing the flow of water in the drain with any connections to a municipal drain.
- Use pea stone backfill, filter cloth or mortar for structural support around connections to closed municipal drains.
- Include well-constructed outfall structures with connections to open municipal drains, as indicated in Section 7.17.



7.15 Site Clean-up and Restoration

- Site clean-up and restoration is a landowner responsibly (see Section 1.2).

7.16 Inspection

Conduct inspections during construction to ensure conformance with plans and specifications. For inspection purposes, under the *Agricultural Tile Drainage Installation Act, 1990*, the contractor provides equipment and services required for the inspection.

The following items should be inspected:

- Quality of pipe (Section 6)
- Drain location (Section 7.5)
- Pipe depth and grading (Sections 2.16 and 7.6)
- Trench width at top of pipe (Section 7.8)
- Joint spacing and alignment of drain tile (Section 7.7)
- Laying pipe (Sections 7.7 to 7.9)
- Connections (Section 7.12)
- Blinding (Section 7.14)
- Backfilling (Section 7.14)
- Filter, envelope, stabilizing materials and placement (Section 6.6)
- Outfalls (Section 3.2)
- Auxiliary structures (Section 3)
- Recording of alterations to the original plan (Section 2.8)

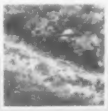
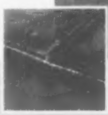
Correct the problem if a drain pipe is not installed to specification. If the deviation from specification occurs along the whole length, install a new drain pipe and don't attempt remedial measures. If the deviation occurs only over a section of the drain pipe, just replace the affected section.

7.17 Outfall Structures

Protect drains discharging into a ditch with a length of continuous rigid, non-perforated end pipe (see Section 3.2). Provide ultra-violet protection for plastic end pipes.

- Install the end pipe as soon as the trench is constructed.
- Follow end pipe diameter recommendations in Table 9.
- Attach a hinged grate to the end pipe, with grate openings that don't exceed 25 mm (1 in.).
- Ensure the outfall is a minimum of 300 mm (12 in.) above normal water level and extends beyond the toe of the slope.
- Control erosion at the outfall.
- Place backfill at the outfall in 75 mm (3 in.) layers and tamp well for a distance of 5 m (16.4 ft) from the outfall to the same density as the surrounding soil.
- Seal the joint between drain pipe and end pipe securely using filter cloth and a coupler.
- Offset the subsurface drain from the centre line of a surface watercourse by one-third the width of the watercourse.
- Place geotextiles under bank erosion control materials for drainage and stability.
- Install an erosion control structure when a surface watercourse enters the ditch at the same location as a subsurface drain.
- In areas where fine sand or iron compounds may enter a drain, consider an individual outfall for each drain.
- Install permanent markers showing the location of the outfall structures.



8. Outlets

8.1 Existing Subsurface Drains

Carefully examine any existing subsurface drains to be used as an outlet for a drainage system. Ensure drains are functioning properly and free from defects which may cause them to fail. Existing drains must be able to provide sufficient capacity to carry the added flow from the proposed drainage system, and provide enough depth to install all drains in the new system at their optimum depth.

8.2 Private Open Ditches

Open ditches provide an adequate outlet for surface and subsurface drainage when the drainage area is less than 200 ha (500 ac) and the ditch-bottom slope is greater than 0.05%, and when these recommendations are followed.

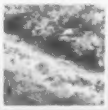
- A minimum distance of 300 mm (12 in.) between the bottom of the tile outfall and the normal water level, if available.
- Increase this clearance to 450 mm (18 in.) if the ditch is in soil subject to erosion and deposition.
- Minimum bottom width of the ditch is 1 m (3 ft).
- Limit maximum side slopes for unprotected ditch banks to ratios listed in Table 10.
- Design for as uniform a cross-section as possible.
- Review existing channels in similar material to verify the stability of a selected side slope ratio.
- Increase the side slope ratio when ditch banks remain submerged. Ensure side slopes of an open ditch are not steeper than the angle of repose of the soil the ditch passes through.
- Ditches of small section need frequent cleaning.

For watershed areas greater than 200 ha (500 ac), individually design ditches that serve as outlets for flow and capacity.

Table 10. Maximum Side Slope Ratios for Open Drains

Soil Materials	Channel Depth <1.2 m (4 ft) (vertical:horizontal)	Channel Depth >1.2 m (4 ft)	Maximum Velocity m/s (ft/s)
Peat, stable organic	1:1	1:1.5	0.5 (1.6)
Heavy clay (>35% clay)	1:1.5	1:2	1.5 (5.0)
Clay/silt loam (10-35% clay)	1:2	1:2.5	1.0 (3.3)
Sandy loamy (<10% clay)	1:3	1:4	0.75 (2.5)
Clay of marine origin and/or banded with sand or silt (subject to low stability when saturated)	1:4	1:4	0.5 (1.6)
Sandy or silty with high water table and/or lateral seepage	1:4	1:5	0.5 (1.6)



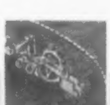


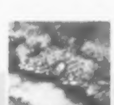

8.3 Pump Outlets

- Consider a pumped outlet instead of a long, costly drain or a deep outlet ditch. A pump can also drain small, isolated areas which can't drain by gravity on individual farms. This is helpful as very productive land is often in lower areas.
- Design a subsurface drainage system as outlined in Section 2 and connect the main drain into a sump, and, or a pond storage ditch. A pump lifts the water to a gravity outlet.
- Using a self-priming submersible sump pump handles high capacity at a low cost. Determine pump capacity required from Table 11, and select pump on the basis of pump capacity and lift. Pump lift must not exceed 3 m (10 ft).

Table 11. Design Values for Pump Drainage

Pump and Motor Capacity					Maximum Storage Volume Required		
	Tile Drain Discharge		Surface and Tile Drain Discharge		Automatic Operation		Manual Operation Surface and Tile Drain Discharge
Drainage Area	Pump	Motor	Pump	Motor	Tile Drain Discharge	Surface and Tile Drain Discharge	
ha (ac)	L/s (gal/m)	kW (hp)	L/s (gal/m)	kW (hp)	m^3 (ft^3)	m^3 (ft^3)	m^3 (ft^3)
4 (10)	**10** (132)	**1.1** (1.5)	**11** (145)	**1.1** (1.5)	**1.0** (35)	**1.2** (42)	**200** (7,063)
8 (20)	**20** (264)	**1.1** (1.5)	**23** (304)	**1.1** (1.5)	**1.5** (53)	**1.8** (64)	**400** (14,126)
16 (40)	**30** (396)	**1.1** (1.5)	**38** (502)	**1.5** (2)	**2.8** (100)	**3.4** (120)	**600** (21,189)
24 (60)	**40** (528)	**1.5** (2)	**45** (594)	**2.2** (3)	**4.2** (150)	**5.0** (177)	**800** (28,252)
32 (80)	**50** (660)	**2.2** (3)	**60** (792)	**3.7** (5)	**5.7** (200)	**6.8** (240)	**1,000** (35,315)
40 (100)	**60** (792)	**3.7** (5)	**75** (990)	**3.7** (5)	**9.5** (336)	**11.5** (406)	**1,200** (42,378)
60 (150)	**90** (1,188)	**5.5** (7.4)	**115** (1,518)	**5.5** (7.4)	**14.0** (495)	**16.8** (593)	**1,800** (63,566)
80 (200)	**125** (1,650)	**5.5** (7.4)	**150** (1,980)	**7.4** (10)	**18.9** (667)	**22.7** (800)	**2,500** (88,287)



- Where electric power is available, connect an electric motor directly to the pump or by V-belts. Automatic operation is best, when starting and stopping the motor by a float-operated switch or electrode controls located at selected water levels.
- Manual-control pumps have a motor powered by gasoline or diesel fuel or by tractor power-take-off. Ensure the storage capacity doesn't require more than two starts per day.
- Figure 28 shows a typical drainage pump with storage sump, using a submersible sump pump for small areas and subsurface drainage. Figure 29 shows a typical propeller type drainage pump with storage sump where water is from subsurface drainage.
- In silty and sandy soils, don't use the subsurface drain as part of the pumped storage – it may fail because of soil instability. Ensure the stop level is below the outfall of the inlet drain.
- Use a storage sump for subsurface drainage to minimize the number of off-on cycles of the pump. A circular form is best, constructed of corrugated steel, pressure treated wood or poured concrete.
- When using a ditch for storage, deepen it at the pump to provide adequate depth of pump submergence. In Figures 28, the depth to be removed at each operation can be varied, but is usually 600 mm (24 in.) for sump storage with automatic operation, and 300-400 mm (12-16 in.) for ditch storage with manual operation. Minimum storage requirements are given in Table 11. Pump capacity can be reduced when more storage is available than shown in Table 11.
- When surface water is to be pumped, consider additional design information on rainfall rate and recurrence interval, crop damage and surface runoff.

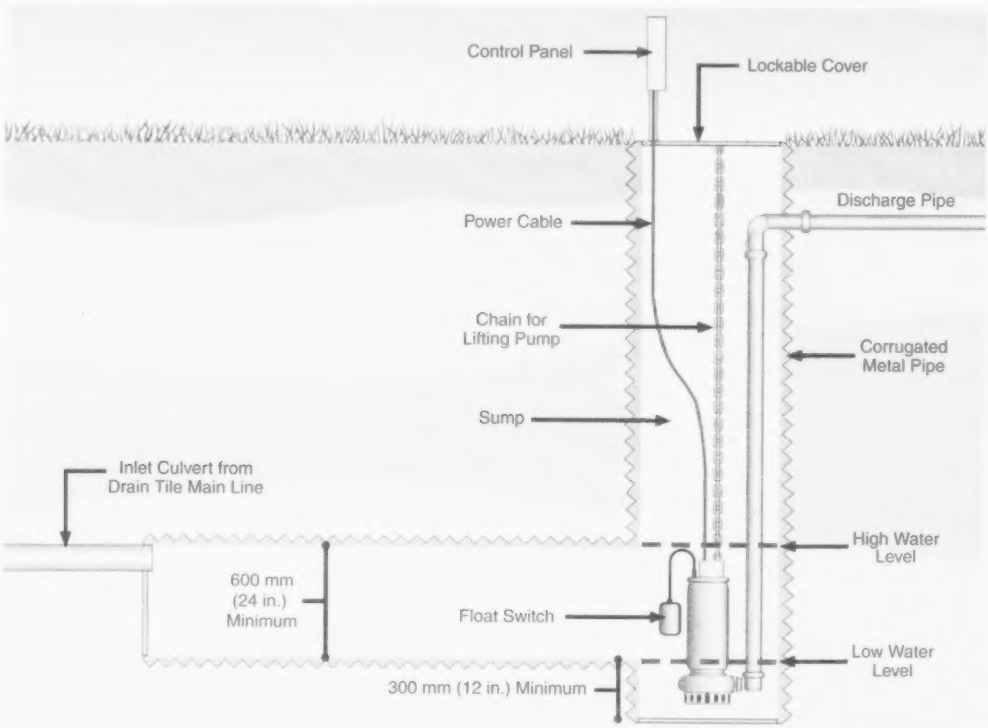
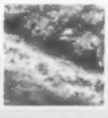


Figure 28. Typical Submersible Drainage Pump





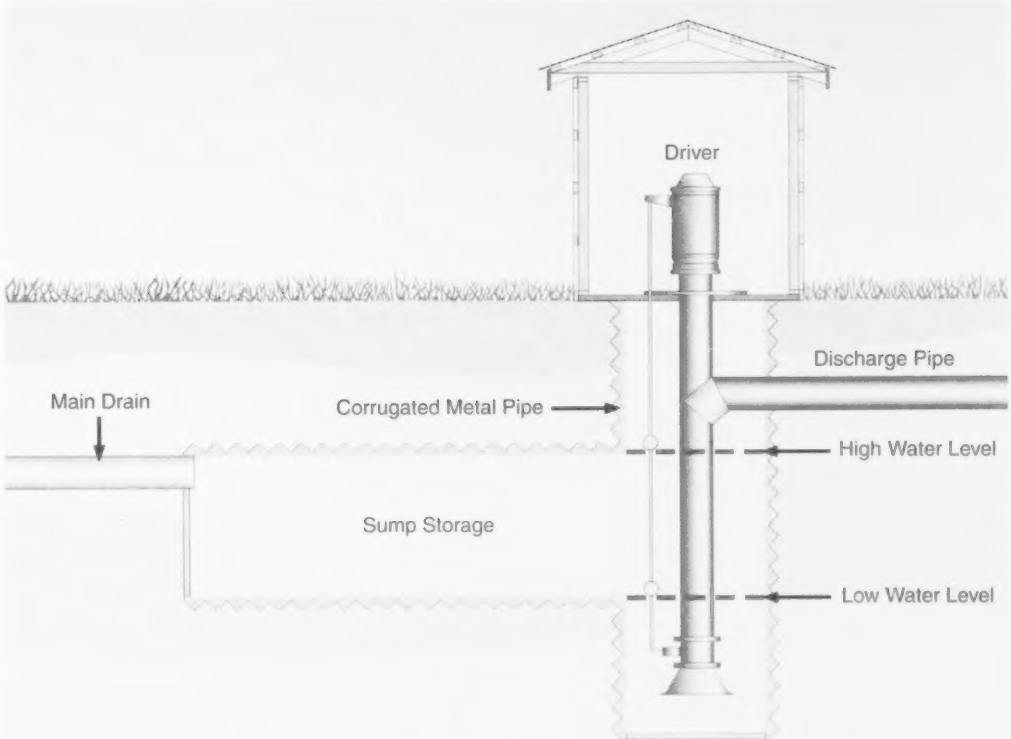



Figure 29. Typical Propeller Drainage Pump

Appendix A

Design Code Detail (see Section 2.4)

Soil maps at many scales cover all or part of a county. On each map, soils are classified broadly into areas known as map units. These units usually comprise a single soil series, soil family or soil association.

Soil series is the name given to a range of soil properties developed on similar parent material with the same soil horizons or layers and properties.

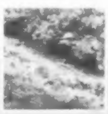
Soil type is the mapped unit consisting of the soil series name plus a descriptor such as clay loam, clay, sand, etc. A soil family is a group of soil series.

Soil association is a group of different soil series developed on similar characteristics and distribution. The soil family and soil association are of primary interest in land drainage although the soil type is the mapped key to the soil family.

Table A1. Generalized Soil Profile Descriptions
(Source of drainage water and order of characteristics)

Group	General Description	"A" Horizons	"B" Horizons	"C" Horizons	Families Included
S1	Overall fine texture. Poor development, soil becomes more compact with depth.	Fine to medium texture; C,SiC or SiCL. Granular structure.	Fine texture; C. Coarse blocky structure.	Fine texture; C. Medium to coarse, blocky, to massive structure.	Clyde, Haileybury, Lincoln, Minesing, New Liskeard, Renfrew, Rideau, South Bay.
S2	Overall medium texture and well structured. Soil becomes more compact with depth. Free water saturation at depths less than 1 metre on parent material.	Medium texture; L, SiL, CL or SiCL. Platy or granular structure.	Fine to medium texture C, SiCL, CL. Medium to coarse, subgranular to angular blocky structure.	Fine to medium texture; C, SiC, SiCL, CL. Medium to coarse, blocky, prismatic to massive structure.	Beverly, Brantford, Brookston, Cane, Conover, Dorking, Elderslie, Haldimand, Huron, Miami, Ontario, Perth, Renfrew, St. Clements, Wellesley, Wilmot.
S3	Overall medium to coarse texture. Sola are deeper than S-2. Fee water saturation at depths less than 1 metre on II C.	Medium to coarse texture; L, SL, LS or S, single grain or fine platy structure.	Medium to coarse texture; SCL, L, SL, S. Platy or fine to coarse subgranular blocky structure.	Fine to medium texture; C, SiC, SiCL, CL, SCL, SiL. Coarse angular blocky structure.	Allendale, Bainsville, Berrien, Bookton, Bucke, Honeywood, Maplewood, Mountain, Nipissing, Tuscola.
S4	Overall medium to coarse texture, with fine textured "B" horizon that may impede internal drainage.	Medium to coarse texture; SCL, SiL, L, SL, LS, S. Medium granular. structure.	Medium to coarse texture. SCL, SiC, SiCL, SCL. Medium subgranular to medium angular. blocky structure.	Medium texture, L, CL, SiL, SCL, SiCL. Weak prismatic to blocky. structure.	Boomer, Earlton, Evanturel. Some northern Ontario Gray, Luvisols will be in this group.
S5	A bog-like depressional soil. The surface layer is organic.	Organic.	Fine to medium sand.	Fine texture; C. Massive.	Belmeade.
S6	Shallow soil over bedrock.	Medium to coarse texture. Medium structure.	Fine to medium texture. Medium subangular to medium angular blocky structure.	N/A	Ameliasburg, Bastard, Brooke, Farmingotn, Franktown, Gerow, Lockport, Shashawandah, Trafalgar, Tweed.






A

Table A1. Generalized Soil Profile Descriptions (cont'd)

(Source of drainage water and order of characteristics)

Group	General Description	"A" Horizons	"B" Horizons	"C" Horizons	Families Included
G1	Soils developed on loam, silt loam and stratified by ponding. Seasonal free water saturation in relation to perched groundwater.	Medium texture; L, SiL. Granular structure.	Medium texture; S, SL. Single grain to medium subangular blocky structure.	Medium texture; L, SiL. May be stratified. Coarse subangular blocky to massive structure.	Colwood, Conestoga, Coutts, Freeport, Grand, Grenville, Guelph, Howland, Killean, London, Lyons, Macton, Magnetawan, Mannheim, Maryhill, Matilda, Moose, Osprey, Otonabee, Vasey, Wabi, Woolwich.
G2	Outwash sands, more than 1 metre deep over clay till, or lacustrine clay. Seasonal free water saturation in relation to perched groundwater.	Coarse texture; S, S1. Granular structure.	Coarse texture; S, SL. Single grain to medium subangular blocky structure.	Coarse texture, S, SL. Single grained loose structure.	Berriedale, Brady, Elmira, Fox, Granby, Kenabeek, Rubicon.
G3	Deep coarse textured soils with seasonal free water saturation in relation to regional groundwater.	Medium to coarse texture; L, SL. Granular structure.	Medium to coarse texture; S, S.L. Granular structure.	Sand or gravel possibly over bedrock.	Alliston, Ayr, Brisbane, Burford, Burpee, Donald, Dumfries, Eastport, Floradale, Fort, Gwillimbury, Hawkesville, Haysville, Heidelburg, Hendrie, Hespeler, Kirkland, Lisbon, Pontypool, Preston, Sargent, Springvale, St. Peter, Sullivan, Tioga, Wendigo.

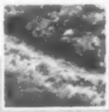
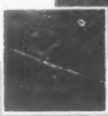
Source: Estimating Saturated Hydraulic Conductivity from Soil Morphology. J.A. McKeague, C. Wong, G.C. Topp. Soil Science Society of America . 46:1239-1244. 1982.

Appendix A

Table A2. Descriptions of Drainage Classes (see Figure A1)

Drainage Characteristics by Soil Class
S1 soils are difficult to drain. The surface is fine-textured and the lower layers are blocky or massive which inhibit rapid water movement. The soil density increases with depth and the hydraulic conductivity is very low. Subsurface drains have been installed in a few soils in the poorly drained class. However, these rely on soil cracking and porosity aids, such as deep tillage to make them successful. Surface drainage is the best water management practice.
S2 soils are somewhat coarser in texture than SI soils and drain better. A finer textured B horizon varies from 600-900 mm (2-3 ft) in depth and will inhibit drainage. Subsurface drainage is quite common in this class. Poorly drained soils are most commonly drained, however, extensive areas of imperfectly and well-drained soils also have subsurface drains. Drains should not be deep and should be placed in the B horizon for best results.
S3 soils are similar to S2 soils inasmuch as a saturated zone occurs at shallow depth due to a perched water table. The A and B soil horizons are coarser in texture. Better soil structure favours subsurface drainage. Drains should be located in the B horizon, above the dense C horizon. S3 soils represent less than 10% of Ontario soils. Subsurface drainage is largely in the imperfectly drained members, with some in the poorly and well-drained members.
S4 soils have a coarse textured surface with good soil structure, and similar qualities for the C horizon. These soils create drainage problems due to the fine textured impermeable B horizon which usually occurs at 300 mm (1 ft) depth. Drainage pipe placed in the parent material may not receive any drainage water due to this dense layer except where a tile trench has disrupted the internal drainage. Soil management will include good surface drainage and a program of deep tillage to break up the B horizon, if the profile permits. There are not many S4 soils in Ontario.
S5 soils have an organic layer of varying depth over sand, or over clay. Before artificial drainage of such soils it is very important to survey the depth of the organic soil. Organic soil over sand is unlikely to drain satisfactorily. Organic soils over clay will consolidate when drained and should be at least 1 m (3 ft) in depth before drainage is even considered. S5 soils are a special problem requiring special considerations. Iron ochre is often a problem in these soils.
S6 soils are usually medium to coarse grained over bedrock at shallow depth. The feasibility of subsurface drainage depends on a detailed soil survey to ensure there is sufficient depth of cover for the drains. Since these soils have so much variation the guide does not give information on the depth and spacing of drains. Each case must be considered on its merits.
G1 soils represent a large area in Ontario (20%) of the drainage activity is in this soil. In terms of soil texture and soil structure all groundwater soils drain readily; however, the differences are in the depth of the soil and whether the cause of the wetness is due to a regional or local water table. The majority of the G1 soils are classed as well drained. The soil profile tends to be a medium texture which does not vary greatly with depth. The G1 and S3 soil profiles are similar inasmuch as wetness is from a perched water table on the C horizon. Less than 1 m (3 ft) for the S3 and over 1 m (3 ft) for the G1. The hydraulic conductivities are different, the G 1 being twice as high.
G2 soils develop wetness from the regional water table, with a summer groundwater at 3 m (10 ft) depth which will create a persistent supply of water in the spring. These soils tend to be coarse-textured and do not represent a very substantial area of drainage activity. Drains should be deep in these soils.
G3 soils also develop wetness from a regional water table, but at a greater summer depth of 12 m (40 ft) or more. About 15% of Ontario soils are in this class with drainage activity being spread over each natural drainage class. Drains should be placed deep in the C horizon to intercept the rising groundwater. These soils are usually coarse grained to gravel.



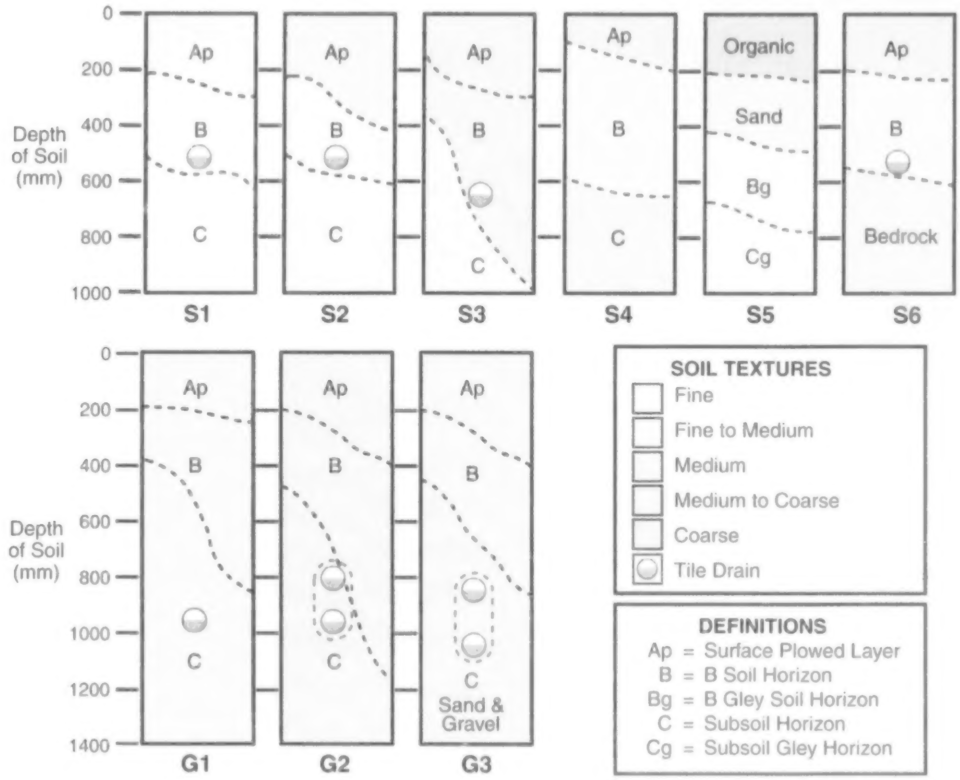
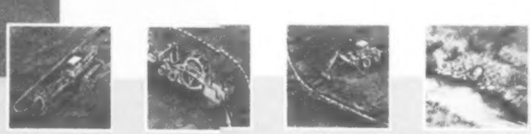


Figure A1. Generalized Soil Profiles of Drainage Codes

Table A3. Hydraulic Conductivity Classes

Drainage Class	Relative Rate	Drainage Code	USDA Hydrologic Group	Hydraulic Conductivity, K			
				m/s	(in./hr)	m/day	(ft/day)
High	R		A	1.4×10^{-4}	(19.84)	12.0	(39.4)
	VR		A	4.6×10^{-5}	(6.52)	3.97	(13.0)
Medium	MR	G2, S3, G1, G3	B	1.2×10^{-5}	(1.70)	1.037	(3.40)
	M	G2	B	4.6×10^{-6}	(0.652)	0.397	(1.30)
	MS	S2	C	1.2×10^{-6}	(0.170)	0.104	(0.33)
Low	S	S3, G3, G1	C	4.6×10^{-7}	(0.0652)	0.040	(0.130)
	VS		D	4.6×10^{-8}	(0.0065)	0.004	(0.013)
	ES	S1, S2	D				

Key: R – rapid, VR – very rapid, MR – moderately rapid, M – moderate, MS – moderately slow, S – slow, VS – very slow, ES – extremely slow



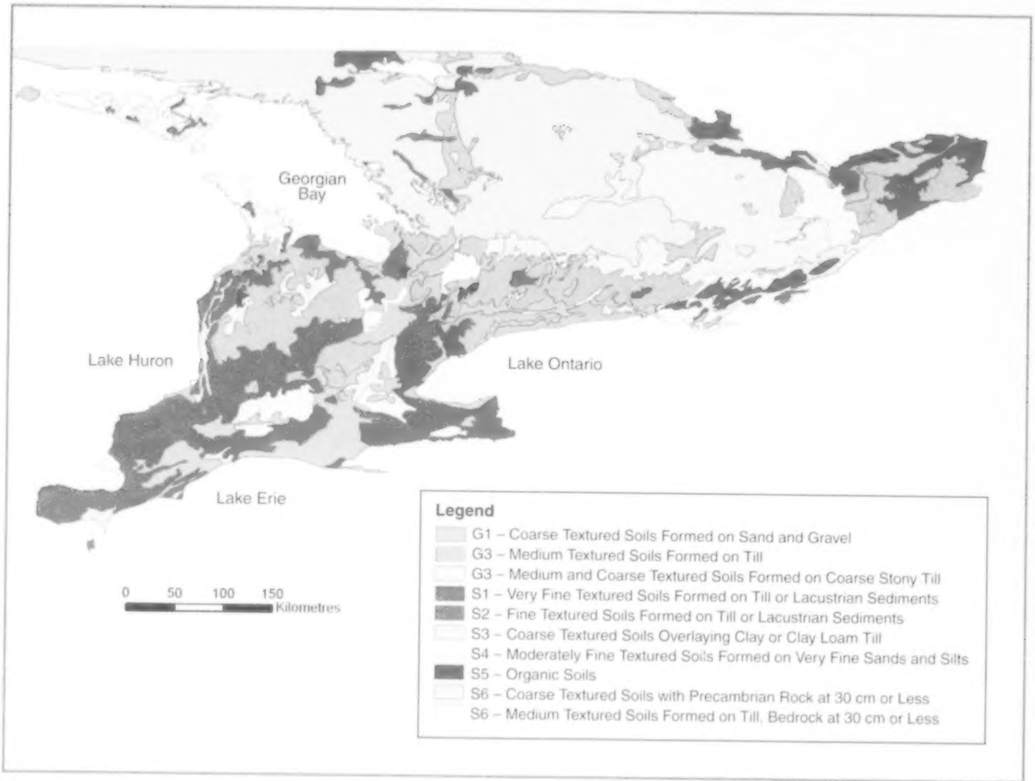


Figure A2. Generalized Subsoil Map Used for Drainage Code Soil Profiles

Sources: Soil Resources and Land Use Hazards in Southern Ontario, B.C. Matthews, Canadian Geographer, 8: 55 – 62, 1956. Overcoming Barriers to Yield. B.D. Kay, R.W. Sheard, L.A. Battison, Notes on Agriculture, p. 17, Vol. XIX, No. 2, 1984.

Table A4. USDA Hydrologic Groups (see Section 2.5)

Hydrologic Soil Groups	Description
A. Low runoff potential	Soils having a high infiltration rate which includes deep sands with very little silt and clay.
B. Moderately low runoff potential	Soils having a moderate infiltration rate when wet includes mostly sandy soils less deep than A. The group has above-average infiltration after thorough wetting.
C. Moderately high runoff potential	Soils having a slow infiltration rate when wet comprise shallow soils and soils containing considerable clay and colloids, though less than group D. The group has below-average infiltration after thorough wetting.
D. Highest runoff	Soils having a very slow infiltration rate, when thoroughly wet, includes potential mostly clays of high swelling percentage. The group also includes shallow soils with nearly impermeable horizons near the surface.

Note: A soil may be placed in two hydrologic soil groups if the soil is drained or undrained.




Natural Drainage Class (drainage code symbol 3)

Natural drainage class refers to the frequency and duration of periods of saturation, or partial saturation, during soil formation, as opposed to altered drainage. Five classes of natural soil drainage are used in this guide.

Table A5. Natural Drainage Classes[1]

Symbol	Description
W	**Well drained** – The soil moisture content does not normally exceed field capacity in any horizon (except possibly the C) for a significant part of the year. Soils are usually free from mottling in the upper metre but may be mottled below this depth. B horizons, if present, are reddish, brownish, or yellowish. Water is removed from the soil readily, but not rapidly.
M	**Moderately well drained** – The soil moisture in excess of field capacity remains for a small but significant period of the year. Soils are commonly mottled in the lower B and C horizons or below a depth of 750 mm (30 in.). The Ae horizon, if present, may be faintly mottled in fine-textured soils and in medium-textured soils that have a slowly permeable layer below the B horizon. In grassland soils the B and C horizons may be only faintly mottled and the A horizon may be relatively thick and dark. Water is removed from the soil somewhat slowly during some periods.
I	**Imperfectly drained** – The soil moisture in excess of field capacity remains in subsurface horizons for moderately long periods during the year. Soils are commonly mottled in the B and C horizons; an Ae horizon, if present, may be mottled. The matrix generally has a lower chroma than in the well-drained soil on similar parent material. Water is removed slowly enough that the soil is wet for significant periods during the growing season.
P	**Poorly drained** – The soil moisture in excess of field capacity remains in all horizons for a large part of the year. The soils are usually very strongly gleyed. Except in high-chroma parent materials the B, if present, and upper C horizons usually have matrix colors of low chroma. Faint mottling may occur throughout. Water is removed so slowly that the soil is saturated periodically during the growing season or remains wet for long periods.
V	**Very poorly drained** – Free water remains at or within 300 mm (1 ft) of the surface most of the year. The soils are usually very strongly gleyed. Subsurface horizons usually are of low chroma and yellowish to bluish hues. Mottling may be present but at depth in the profile. Very poorly drained soils usually have a mucky of peaty surface horizon. Water is removed from the soil so slowly that free water remains at or on the surface during most of the growing season.

[1]Descriptions are taken from p 220 - 221, The System of Soil Classification For Canada, Agriculture Canada, 1972.
Refer to Table A2, Estimating Saturated Hydraulic Conductivity from Soil Morphology, J. A. McKeague, C.Wong, G.C. Topp, SSSA 46 #6, 1239 – 1244, 1982.

Table A6. Slope Classes (drainage code symbol 4)

Code Symbol	Slope Range	Definition	Canada System Soil Classification Slope Classes
1	0-0.5%	Level	1
2	0-2%	Level to nearly level	1 and 2
3	0.5-2%	Nearly level	2
4	0.5-5%	Nearly level to very gentle slopes	2 and 3
5	2-5%	Very gentle slopes	3
6	2-9%	Very gentle to gentle slopes	3 and 4
7	2-15%	Very gentle to moderate slopes	3, 4 and 5
8	6-15%	Gentle to moderate slopes	4 and 5
9	10-30%	Moderate to strong slopes	5 and 6

Soil Capability Subclasses

Subclasses are divisions within classes listed below with the same kind of limitations for agricultural use. There are 13 different kinds of limitations recognized at the subclass level. A brief discussion of six of these subclasses and their designation on maps is as follows.

Undesirable soil structure and/or low permeability (D) – used for soils difficult to till, that absorb water very slowly, or where the depth of the rooting zone is restricted by conditions other than a high water table or consolidated bedrock.

Inundation by streams or lakes (I) – includes soils subjected to inundation causing crop damage or restricting agricultural use.

Moisture limitation (M) – soils where crops are adversely affected by drought owing to inherent soil characteristics. They are usually soils with low water-holding capacity.

Stoniness (P) – soils that are sufficiently stony to significantly hinder tillage, planting and harvesting operations. Stony soils are usually less productive than comparable non-stony soils.

Consolidated bedrock (R) – soils where the presence of bedrock near the surface restricts agricultural use. Consolidated bedrock at depths greater than 1 m (3 ft) from the surface is not considered as a limitation, except on irrigated lands where a greater depth of soil is desirable.

Excess water (W) – soils where excess water, other than that brought about by inundation, is a limitation for agricultural use. Excess water may result from inadequate soil drainage, a high water table, seepage or runoff from surrounding areas.



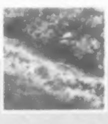
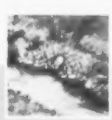



Table A7. Soil Capability Classes (see Table 2)

Class 1	Soils in this class have no significant limitations in use for crops.
Class 2	Soils in this class have moderate limitations that restrict the range of crops or require moderate conservation practices.
Class 3	Soils in this class have moderately severe limitations that restrict the range of crops or require special conservation practices or both.
Class 4	Soils in this class have severe limitations that restrict the range of crops or require special conservation practices.
Class 5	Soils in this class have very severe limitations that restrict their capability to producing perennial forage crops, and improvement practices are feasible.
Class 6	Soils in this class are capable only of producing perennial forage crops, and improved practices are not feasible.
Class 7	Soils in this class have no capability for arable culture or permanent pasture.



B

Appendix B

Flow Chart of Possible Drainage Situations and Solutions

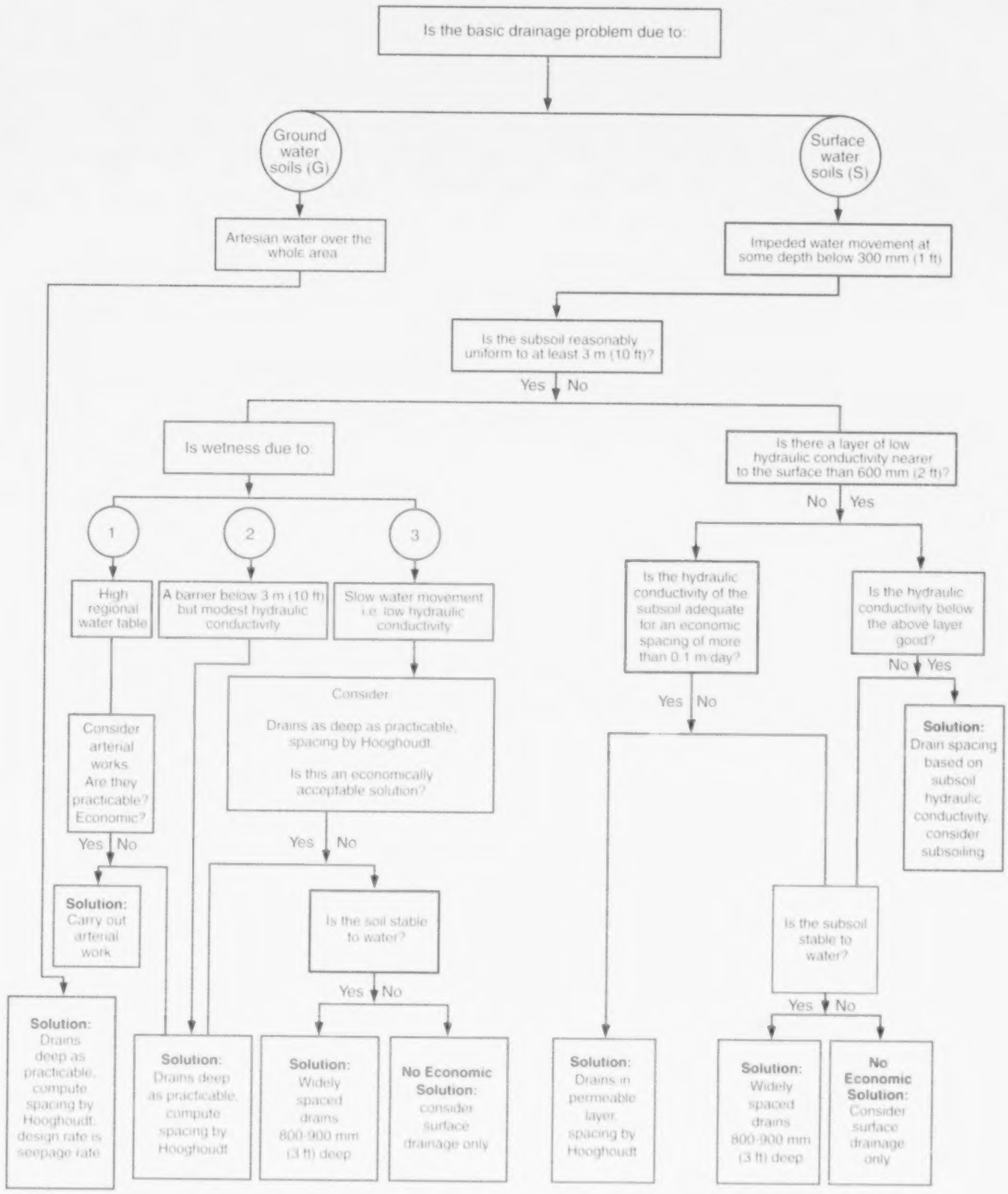
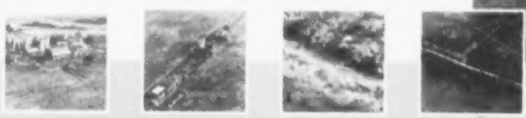


Figure B1. Calculation of Drain Spacing

Appendix B



The Drainage Guide gives an empirical procedure, based on long local experience, to determine drain spacing. Scientifically-based drain spacing can be determined when the required soil information can be determined. Figure B1 is a flow chart describing a procedure to follow to assess the source of the wetness problem before using the following drainage spacing equation. This steady state drain spacing formula is attributed to Hooghoudt (1940) and is presented here as it is widely accepted in practice.

Source: Hooghoudt, S.B. 1940. Bijdrage tot de kennis van enige natuurkundige grootheden van de grond. Versl. Landb. Onderz. No. 46 (14) B:515-707.

Note: see Section 2.6 Calculation of Theoretical Drain Spacing

Hooghoudt's equation states: $S^2 = (4/R)(2K_2 d_e m + K_1 m^2)$, where

- S = drain spacing, m
- K_1 = hydraulic conductivity of the layer above the drains, m/d (B2)
- K_2 = hydraulic conductivity of the layer below the drains, m/d (B2)
- d_e = equivalent depth of conducting soil below drains, or effective depth of flow (B3) dependent on depth to impermeable layer, drain spacing, and drain diameter, m.
- m = mid-spacing water table height, m
- R = drainage rate, m/day (See Section 2.10)

The saturated hydraulic conductivity (K_{sat}) is the amount of water that would move vertically through a unit area of saturated soil in unit time under unit hydraulic gradient. Since measurements are difficult to make and are available for relatively few soils, estimates of saturated hydraulic conductivity are based on soil properties. Soil properties affecting saturated hydraulic conductivity are distribution, size and shape of soil pores. In making estimates, texture is the soil characteristic that exerts the greatest control for many soils. Measure the hydraulic conductivity, K_1 and K_2, in the field. When direct measurements aren't available, estimate these values from soil texture in Figure B2.

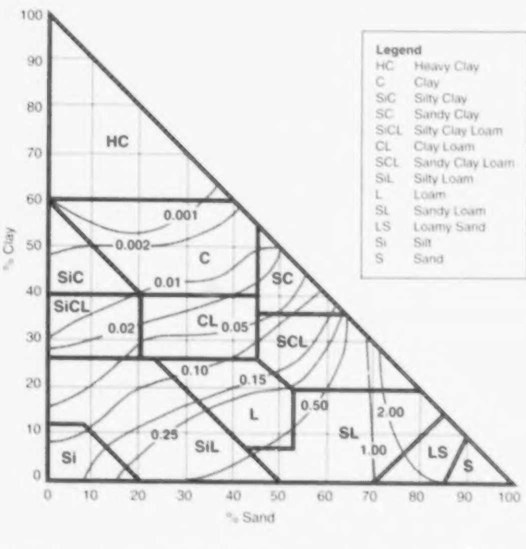
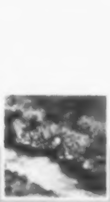


Figure B2. Estimating Hydraulic Conductivity from Soil Texture

As S affects d_e the equation is not directly solvable, and trial and error solutions must be used. However, calculations are less tedious if a spacing S is assumed and the required hydraulic conductivity, K, is calculated. Working in this way, a two layer situation can only be tackled assuming K_1 and K_2 bear some relation to one another; i.e. $K_1 = 2K_2$, $K_1 = 5K_2$, etc.



In this form the equation is:

$$K_2 = (RS^2)/(8\,d_e\,m + 4n\,m^2)$$

where n = the numerical relationship between K_1 and K_2. The equivalent depth, d_e, for a selected drain spacing and depth to impermeable layer, can be estimated from Figure B3.

In Figure B4 the drainage rate, R, has been assumed to be 0.01 m/day (cereal crop), because this has reasonable application in Ontario. Strictly, one should vary the design criteria to suit the crop and climatic conditions of the area. Present knowledge does not allow this to be done with any precision. In the calculations, the midspacing water table height between drains, m, has been chosen as 50 cm (20 in.). This may be interpreted as 50 cm (20 in.) of freeboard, or unsaturated soil, with a drain depth of 1 m (3 ft) or 30 cm (12 in.) and a drain depth of 80 cm (32 in.), or any combination. A spacing of 10 m (33 ft) has been chosen as the minimum likely to be economic for most cases. Figure B4 illustrates the way hydraulic conductivity and drain spacing are related for a number of positions of the impermeable layer. The impermeable layer is a layer having less than $^1/_{10}$ of the hydraulic conductivity of the layer above it. Note that the position of the impermeable layer is critical when it's close to drain depth, but decreases in importance as the depth of the layer increases.

Soil Drainability

It's difficult to determine whether a soil will drain rapidly enough to permit economical subsurface drainage. Pore spaces nearly full of water at field capacity don't transmit much water down through the pores to the drain lines. The soil pore air space that drainage water moves through is the total pore space minus space occupied by water held at field capacity (N at $^1/_3$ bar). This value is the drainage capacity.

Drainage capacity (%) = Total porosity (%) – porosity at field capacity.

If the drainage capacity is too low (<10%), soil water won't drain through tile drains

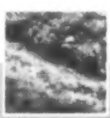
Table B1. Representative Physical Properties of Soils

Soil Texture	Bulk Density g/cc	Total Porosity % Volume	Field Capacity % Saturation	Wilting Point % Saturation
Sandy	1.65 (1.55-1.80)	38 (32-42)	39 (31-47)	17 (10-24)
Sandy loam	1.50 (1.40-1.60)	43 (40-47)	49 (38-57)	21 (15-26)
Loam	1.40 (1.35-1.50)	47 (47-51)	66 (66-82)	30 (26-34)
Clay loam	1.35 (1.30-1.40)	49 (47-51)	74 (66-82)	36 (32-40)
Silty clay	1.30 (1.25-1.35)	51 (49-53)	79 (72-86)	38 (34-42)
Clay	1.25 (1.20-1.30)	53 (51-55)	83 (76-89)	40 (37-43)

Note: Numbers in parentheses indicate normal range.

Source: Israelsen, O.W., and V.E. Hansen, 1962. Irrigation principles and practices, 3rd ed., John Wiley and Sons, New York.



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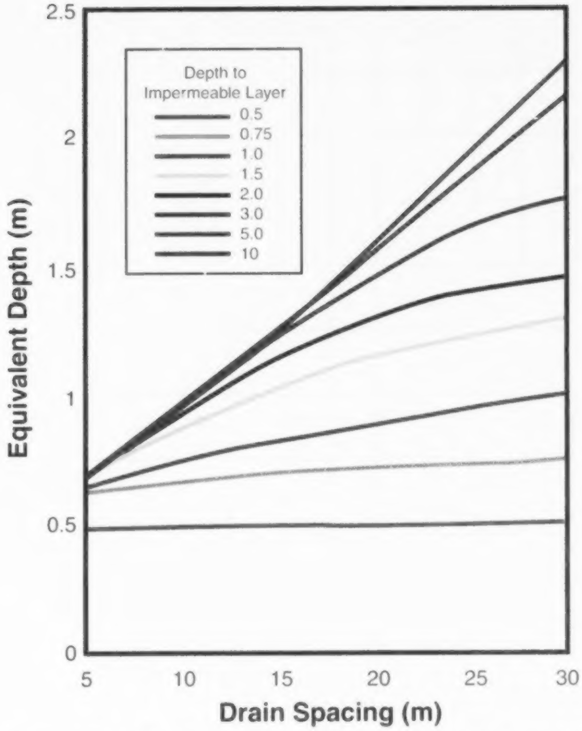


Figure B3. Estimation of Equivalent Depth for a Selected Drain Spacing (100 mm drain diameter)

Source : Lahye, J. 1960. Note sur la formule de Hooghoudt. Bull. techn. du Genie rural (Min. de l'Agr), no. 49-1.

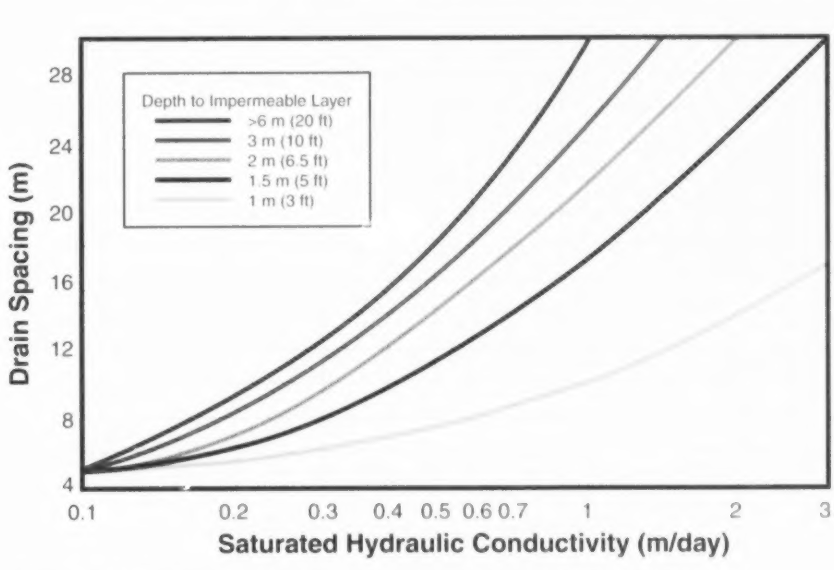
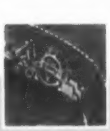
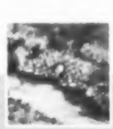


Figure B4. General Relation Between Saturated Hydraulic Conductivity and Drain Spacing

Appendix B



Appendix C

Additional Information

Table C1. Lateral Drain Pipe Length Required to Drain an Area

Lateral Spacing m (ft)	Length of Pipe Required * m/ha (ft/ac)
6 (20)	1,667 (2,178)
9 (30)	1,111 (1,452)
12 (40)	833 (1,089)
15 (50)	667 (871)
18 (60)	556 (726)
25 (66)	400 (660)

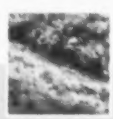
**Length of pipe required for mains and submains are not included in these figures.*

Table C2. Measurement Conversion Factors

Symbol	When You Know	Multiply By	To Find	Symbol
Length:				
mm	millimetres	0.039	inches	in
m	metres	3.281	feet	ft
km	kilometres	0.621	miles	mi
Area:				
m^2	square metres	10.764	square feet	ft^2
m^2	square metres	0.0001	hectares	ha
km^2	square kilometres	0.386	square miles	mi^2
ha	hectares	2.471	acres	ac
ha	hectares	10764.0	square feet	ft^2
ac	acres	43,560	square feet	ft^2
Volume:				
L	litres	0.264	gallons (US)	gal (US)
L	litres	0.220	gallons (Imp)	gal (Imp)
L	litres	0.0353	cubic feet	ft^3
L	litres	0.001	cubic metres	m^3
m^3	cubic metres	264.2	gallons (US)	gal (US)
gal (US)	gallons (US)	0.134	cubic feet	ft^3
Rate:				
L/s	litres per second	15.850	gallons per minute	gpm (US)
L/m	litres per minute	0.264	gallons per minute	gpm (US)
m^3/s	cubic metres per second	35.31	cubic feet per second	cfs
Other:				
kW	kilowatts	1.341	horsepower	hp

To convert from Imperial to Metric units divide by the number in column 3.
For example, 1.5 in. = (1.5 ÷ 0.039) = 38.1 mm.



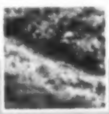



Appendix D

Glossary

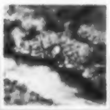
Backfilling	Placement of excavated soil in the trench after blinding has been completed.
Bedding	The earth foundation of the trench together with the select material around and over the drain, including envelope and filter material where used.
Blinding	Placement of select soil around a drain to prevent damage or misalignment when the trench is backfilled and to allow water to flow freely to the drain.
Coefficient of roughness	Factor expressing the frictional resistance to flow of a channel surface or a drain interior.
Connections	Fittings used to join two drain lines.
Continuous pipe	Extended length of pipe without perforations or unsealed joints.
Drain invert	The lowest part of the internal cross-section of a lined channel or drain pipe.
Drainage area	Area from which drainage water is collected and delivered to an outlet. Sometimes referred to as the watershed area for a particular drain.
Drainage coefficient or drainage rate	The depth of water to be removed from an area within 24 hours, in mm/day (in./day).
Drainage system	Collection of surface ditches or subsurface drains, together with structures and pumps used to collect and dispose of excess surface and subsurface water from an area.
Equivalent depth	The equivalent depth (d_e) is a function of the drain spacing, drain tube radius and depth (d) to the impermeable layer below the drain centers. It is the effective flow through the soil below the drains. Hooghoudt has suggested the use of d_e to replace the actual depth to the impermeable barrier as a means of accounting for the physical convergence of flow lines near the drain.
Gley	Gleization in poorly drained soils involves the reduction of iron into coloured mottles and concretions. Gley layers often have increased density.
Grade or gradeline	Degree of slope of a channel or natural ground.
Hydraulic conductivity	The rate at which water moves through a soil
Impermeable layer	If the permeability of the subsoil is about one-tenth that of the soil above it, the subsoil can be considered impermeable.






Interceptor line or drain	Surface ditch or subsurface drain, or a combination of both, designed and installed to intercept several lines to keep the number of crossings at highways and similar locations to a minimum (also called collector lines).
Junction	Point of intersection of two or more surface ditches or subsurface drains.
Land grading	The shaping of the land surface by cutting, filling and smoothing to planned grades so that each row or surface slopes to a drain without ponding.
Land smoothing	Shaping the land surface with a land plane or land leveller to eliminate minor depressions and irregularities without changing the general topography. The depth of cut in this operation is generally small and limited by the kind of equipment used. Land smoothing is also the finished operation in land grading.
Lateral drain	Secondary drain that collects excess water from a field.
Main drain	Principal drain that conducts drainage water from the lateral drains and submains to an outlet.
Pipe	Any product such as corrugated plastic drainage tubing, clay or concrete drain tile, or other type of conduit.
Pumping plant	One or more pumps, power units, and appurtenances for lifting drainage water from a collecting basin to a gravity outlet.
Submain	Branch drain off the main drain which collects discharge water from lateral drains.
Subsurface	The removal of excess water from below the soil surface by means drainage of drain tile, perforated pipe, mole channels, or other devices.
Surface drainage	The diversion or orderly removai of excess water from the surface of the land by means of improved natural or constructed channels, supplemented when necessary by sloping and grading of land surfaces to these channels.
Tile	Drain pipe made of burned clay, concrete, or similar material, in short length usually laid with open joints to collect and carry excess water from the soil.
Tubing	A flexible drain pipe that gains part of its vertical soil load-carrying capacity from lateral support of the surrounding soil.
Watershed	Total land area above a given point on a stream or waterway that contributes runoff to that point.
Water table	The upper surface of a saturated zone within the soil.



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